PONTIFICIA UNIVERSIDAD CATÓLICA DEL PERU

FACULTAD DE CIENCIAS E INGENIERIA

"DIAGNÓSTICO Y EVALUACIÓN DE LA RELACIÓN ENTRE EL TIPO ESTRUCTURAL Y LA INTEGRACIÓN DE LOS CONTRATISTAS Y SUBCONTRATISTAS CON EL NIVEL DE PRODUCTIVIDAD EN OBRAS DE CONSTRUCCIÓN"

Tesis para optar el Título Profesional de
INGENIERO CIVIL

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RESUMEN EJECUTIVO

La presente investigación tiene por objetivos el determinar la evolución de la productividad respecto a la mano de obra en Lima Metropolitana y relacionarla con el tipo de estructura del proyecto y con el grado de integración entre los contratistas y subcontratistas.

Para ello se realizaron mediciones en 26 obras a nivel de Lima Metropolitana, en las cuales se calificó el trabajo de los obreros del sector construcción en trabajo productivo (TP), trabajo contributorio (TC) y trabajo no contributorio (TNC). Además, se obtuvo información adicional mediante encuestas y entrevistas al personal que labora en la obra, tanto del área técnica – administrativa como el personal obrero y los subcontratistas.

Con fines comparativos, se utilizó el criterio de evaluación del trabajo de la tesis predecesora del año 2000, sin embargo se presenta también una nueva forma de evaluación, la cual podría ser utilizada para futuras investigaciones.

En cuanto al tema de subcontratos, se presenta un esquema de clasificación de la relación que tienen con los contratistas. En éste se contemplan aspectos como la calidad del contrato firmado entre ambas partes, la cantidad de proyectos que llevan desarrollando juntos, la intensidad de control que ejerce el contratista al subcontratista, entre otros. Luego de clasificar los subcontratos de cada obra medida, se procede a compararlos con el tiempo productivo obtenido en el análisis anterior y concluir si existe relación entre ambos valores. Se termina éste análisis con el listado de los problemas más frecuentes que impiden una buena integración entre ambas partes.

De manera similar, cada obra se clasificó según el tipo de estructura, utilizando para ello la Norma Peruana Sismorresistente. Se pone énfasis en que el tipo de estructura define el proceso constructivo del proyecto, haciendo que ciertas prácticas, materiales y tecnologías sean más utilizados en un tipo de estructura que en otro.
Se relaciona el tipo de estructura con el indicador de productividad para obtener cual de los sistemas estructurales ofrece mayores ventajas en cuanto a uso adecuado de la

mano de obra y, además, también se compara con un indicador basado en la velocidad por metro cuadrado de techo construido por día.

Luego, se concluye con la identificación de los problemas que han ocasionado los resultados obtenidos respecto a los de hace cinco años; se recomiendan acciones para mejorar en un futuro respecto a la productividad, a los subcontratos y al tipo de estructura.

Finalmente, se establecen pautas y propuestas para orientar el trabajo de investigaciones posteriores.

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TEMA DE TESIS PARA OPTAR EL TÍTULO DE INGENIERO CIVIL

- Área de Construcción -

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TÍTULO
"Diagnóstico y Evaluación de la Relación entre el Tipo Estructural y la Integración de los Contratistas y Subcontratistas con el Nivel de Productividad en Obras de Construcción".

PLANTEAMIENTO DEL PROBLEMA
A partir del análisis sobre la productividad en Lima Metropolitana que se realizó en el año 2000 y considerando los cambios en la construcción que han ocurrido en estos últimos años, surge la inquietud de conocer nuestro estado actual respecto al tema.

El uso de mano de obra especializada, a través de los subcontratos, ha generado un cambio en el modo de gestionar la obra y en el proceso mismo de su ejecución. Se plantea, por ello, el análisis del vínculo contratista–subcontratista en Lima Metropolitana y su relación con la productividad.

Además, despierta el interés la creencia de que el tipo de estructura del proyecto tiene incidencia en la productividad debido a su procedimiento constructivo, por lo que se investigará al respecto.

OBJETIVOS
- Evaluar la productividad en proyectos de edificación en Lima Metropolitana, en el año 2005.
- Evaluar la relación existente entre la productividad en la construcción de edificaciones para viviendas con el grado de integración entre los contratistas y los subcontratistas.
- Evaluar la relación existente entre la productividad en la construcción de edificaciones para viviendas con el tipo de estructura utilizado.

METODOLOGÍA
Se realizará un estudio de tiempos en distintas obras en Lima Metropolitana, a fin de obtener un resultado representativo del nivel de ocupación de la mano de obra en tres tipos de tiempo: productivo, contributorio y no contributorio. Estos porcentajes de tiempos serán tomados como un indicador del nivel productividad, con el cual se podrá hacer el diagnóstico indicado en los objetivos.

Además, se obtendrá la información necesaria de las obras para clasificarlas de acuerdo a características similares según el grado de integración con los subcontratos y el tipo de estructura, y se relacionarán con su productividad.

Máximo: 100 páginas

Lima, 22 de Septiembre de 2005.

Este trabajo está dedicado a todos aquellos familiares y amigos que me brindaron su apoyo.

Cristhian

Esta investigación es el fruto del apoyo constante de mi familia y mi enamorada. A todos ellos, mi gratitud y amor eternos.

Pedro A.

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i. PRESENTACIÓN

1. Introducción

Actualmente, debido al apoyo brindado por el estado a través de facilidades de financiamiento como el programa de MIVIVIENDA, el mercado en el sector de la construcción se ha incrementado.

Dicho auge trae consigo una mayor competencia entre las empresas constructoras, las cuales deben generar la oferta más barata sin sacrificar su utilidad. Para ello cuentan con dos caminos, siendo el primero el sacrificar rubros como la seguridad, calidad, entre otros; y obligar que sus trabajadores (técnicos, administrativos, subcontratistas, etc) disminuyan sus costos.

El otro camino es la aplicación de nuevas tecnologías[i] con creatividad y de forma adecuada que les permitan destacar entre la competencia y así establecer un liderazgo en el mercado.

Suponiendo que el camino escogido por las empresas es el segundo, y motivados por un trabajo llevado a cabo en el año 2000, es que decidimos hacer realidad este proyecto cuya finalidad es la de obtener un "indicador de productividad" (IP) que nos permita calificar la situación actual de la construcción en Lima, además de establecer la relación que mantiene éste con el tipo de estructura del proyecto y con el nivel de integración de los subcontratos.

El indicador escogido presenta dos características fundamentales:

La primera es que se enfoca en el insumo Mano de Obra. Esto se debe a que de todos los recursos de los que hace uso la construcción (mano de obra, materiales, herramientas entre otros), la mano de obra es la que presenta mayor variabilidad ya que se ve influenciada por diversos factores, tales como sicológicos, climáticos,

[i] Daft, R. L. define tecnología como las herramientas, técnicas, maquinarias y acciones (tales como métodos de trabajo y administrativos) usados para transformar aquellas entradas organizacionales (organizational inputs) en salidas (outputs).

el modo como son organizados, etcétera. Por el contrario los otros recursos empleados, siempre y cuando sean bien controlados, no van a variar de forma significativa ya que básicamente dependen de un metrado el cual se obtiene directamente de los planos o del campo y no va a sufrir variación a menos que esté mal realizado (Por dar un ejemplo, los metros cúbicos de concreto a utilizar van a ser los mismos, ya sea que se lleve a cabo la obra en 1 mes como en 1 año).

El término productividad, según Koontz[ii], se define como la relación producto – insumo en un periodo de tiempo dado y con la debida consideración de calidad. Lo cual implica que cuando nos referimos a la productividad, la estamos asociando implícitamente a un insumo dado. En nuestro caso dicho insumo es la mano de obra y la producción de ésta va a depender de la actividad que se está analizando.

La segunda característica es que el indicador que se presenta no nos brinda la productividad, tal y como se define líneas arriba, de forma cuantitativa, ya que no incluye de manera directa en su cálculo la producción del grupo humano involucrado. Lo que se pretende es que, a través de un estudio de tiempos, se distinga la cantidad de éste que se dedica realmente a actividades que agregan valor. De este modo se puede evaluar de forma indirecta la productividad bajo el precepto de que se obtiene mayor producción si se dedica la mayor cantidad del tiempo a actividades productivas.

Según un documento publicado por Sergio Maturana, Luis Alarcón y Mladen Vrsalovic[iii]: "Existen distintos métodos para la medición de la productividad, muchos de los cuales están basados en datos cuantitativos. Cuando sea posible, los estándares debieran basarse en hechos y datos antes que en la intuición y la subjetividad. Sin embargo, cuando hay falta de tradición en la medición de operaciones, la información cuantitativa para la medición de la productividad puede no estar disponible. En ese caso, la medición de la productividad de forma subjetiva es una posible solución."; por lo tanto se acepta el uso del IP como medida subjetiva de la productividad de la mano de obra.

[ii] Administración (Harold Koontz) – Capítulo 1: Administración: Ciencia, teoría y práctica
[iii] Achieving collaboration in the construction supply Chain: An Onsite subcontractors' Evaluation Methodolody

El IP se considera útil, básicamente por los siguientes motivos:

- Permite hacer un diagnóstico de la situación actual de la construcción en Lima, el cual a su vez nos permite compararnos con otras realidades.
- Contribuye a establecer una comparación entre los resultados obtenidos hace 5 años. Esto último es de vital importancia ya que, tal y como se menciona en el Rethinking Construction Report[iv], la medición efectiva del desempeño cumple un rol fundamental en todo proceso de mejora.
- Sirve como punto de comparación para investigaciones futuras.
- Permite identificar puntos débiles a reforzar a fin de no cometer los mismos errores en el futuro.

2. Alcances

El alcance de la presente investigación está delimitado por los parámetros que se listan a continuación:

- *Área de investigación:*

El campo de acción de nuestra investigación es Lima Metropolitana, ubicada en la provincia y departamento de Lima, Perú.

- *Objeto de Estudio:*

Se realiza el estudio en obras de construcción de Viviendas Multifamiliares que estén en la etapa de casco estructural, es decir, durante la construcción de los elementos estructurales de la edificación.

[iv] Este reporte fue entregado por The Task Force dirigida por John Egan al Adjunto del Primer Ministro (Deputy Prime Minister), John Prescott en referencia al mejoramiento de la calidad y la eficiencia de la construcción en El Reino Unido, para reafirmar los ímpetus de cambio y para que la industria se vuelva más responsable de modo de satisfacer las necesidades de los clientes.

Cabe resaltar que las empresas constructoras de dichos proyectos deben ser formalmente constituidas, excluyendo del análisis los casos de autoconstrucción, obras sin licencia municipal, etc.

- Enfoque del Estudio:

Dentro de los tres recursos empleados en la construcción (mano de obra, equipos y herramientas; y materiales), el presente estudio se centrará en analizar la productividad de la mano de obra a través de un indicador basado en un estudio de tiempos el cual denominamos Nivel General de Actividad de Obra (NGO). Dicho indicador se definirá más adelante en el presente informe.

- Tolerancia del Estudio:

Se espera obtener resultados estadísticamente válidos y representativos de Lima Metropolitana, con un error menor al 5%.

3. Objetivos

Nuestros objetivos son los siguientes:

1. Obtener un resultado representativo de la productividad a partir de un indicador. Esto es a nivel de Lima Metropolitana.

2. Comparar la productividad actual con la obtenida en el estudio del 2000.

3. Reconocer la situación de la subcontratación en el Perú y comparar la influencia de ello en la productividad.

4. Reconocer la influencia del tipo de estructura en la productividad del proyecto y determinar la óptima.

4. Hipótesis

De acuerdo a nuestros objetivos, nos planteamos las siguientes hipótesis:

1. Nuestra productividad ha mejorado con respecto a hace cinco años.

2. El tipo de estructura influye en la productividad, siendo la más productiva aquella cuyos elementos resistentes son muros delgados de concreto armado.

3. El grado de integración de los subcontratos influye en la productividad, siendo aquellos que tienen un grado alto de integración, los que tienen mayor productividad.

ii. ESTADO DEL ARTE

1. INTRODUCCION

El modo de construcción tradicional presenta varios paradigmas que limitan las ganancias de los inversionistas en ese sector, quiénes no necesariamente incurren en pérdidas si no que dejan de ganar buenas cantidades de dinero.

Para poder aprovechar esos montos, surgen nuevas tendencias e ideologías que lo que buscan es romper con los paradigmas que limitan la calidad, la seguridad y que promueven un sistema en donde hacer perder al otro es la consigna por excelencia.

Dado que consideramos a la construcción como una industria, es importante ofrecer a su cliente un producto de buena calidad, brindar seguridad a sus empleados, establecer vínculos de negocios con sus subcontratistas de modo que ambos ganen, y estudiar y optimizar procesos para obtener mayores ganancias.

Las próximas hojas de este acápite buscan orientarnos y explicarnos las tendencias que han hecho posible la ruptura de tales paradigmas y que han sido tomadas como base de la investigación que luego se presenta.

2. ESTUDIO DE TIEMPOS Y MOVIMIENTOS

El estudio del trabajo es el examen sistemático de los métodos para realizar actividades con el fin de mejorar la utilización eficaz de los recursos y de establecer normas de rendimiento con respecto a las actividades que se están realizando.

Por tanto, el estudio del trabajo tiene por objeto examinar de qué manera se está realizando una actividad, simplificar o modificar su método operativo para reducir el trabajo innecesario o excesivo, o el uso antieconómico de recursos, y fijar el tiempo normal para la realización de esa actividad. En otras palabras, se busca rechazar el desperdicio en todas sus formas – de materiales, tiempo, esfuerzo o dotes humanas – y no aceptar sin discusión que las cosas de hagan de cierto modo “porque siempre se hicieron así”.

El estudio del trabajo comprende varias técnicas, y en especial el estudio de métodos y la medición del trabajo.

2.1. Estudio de métodos

También conocido como estudio de movimientos, es el registro y examen crítico sistemáticos de los modos de realizar actividades, con el fin de efectuar mejoras, tales como:

- Encontrar el mejor método de trabajo.
- Fomentar en todos los empleados la toma de conciencia sobre los movimientos.
- Desarrollar herramientas, dispositivos y auxiliares de producción económicos y eficientes.
- Ayudar en la selección de nuevas máquinas y equipo.
- Capacitar a los empleados nuevos en el método preferido.
- Reducir esfuerzos y costos.

2.2. Medición del trabajo

O estudio de tiempos, es la aplicación de técnicas para determinar el tiempo que invierte un trabajador calificado en llevar a cabo una tarea según una norma de rendimiento preestablecida.
Este estudio se relaciona con la investigación de cualquier tiempo improductivo.

En un principio, se plantea que el trabajo en sí consta de dos partes. La primera parte es el contenido básico de trabajo, la cual fija el tiempo mínimo irreducible que se necesita teóricamente para obtener una unidad de producción.
La segunda parte es el contenido de trabajo suplementario, es decir, el tiempo adicional al teórico que sucede debido a deficiencias en el diseño o en la especificación del producto o de sus partes, o a la utilización inadecuada de materiales, o debido a la influencia de los recursos humanos.
Es la segunda parte la que debe ser estudiada y minimizada para disminuir el tiempo de producción y aumentar la productividad.

3. LEAN PRODUCTION

"Lean Production" es una filosofía de la industria manufacturera que puede entenderse como una nueva forma de diseñar las operaciones optimizando los sistemas de producción para alcanzar los requerimientos de los clientes.

Fue desarrollada en la compañía japonesa Toyota, por el ingeniero Taichi Ohno[i] a finales de la década de los cincuenta, influenciado por los criterios de W. Edwards Deming[ii] de Total Quality Management[iii] (TQM - Gestión de Calidad Total).
Ohno planteó objetivos concretos para el diseño de su sistema de producción, producir un carro para los requerimientos específicos de un cliente y entregarlo instantáneamente sin el uso de inventarios.

Orientados a alcanzar estos objetivos, la filosofía de Lean Production plantea medidas como la reducción de pérdidas, las cuales están definidas como cualquier actividad que no contribuya a la generación de valor para el cliente

"El Lean Production está orientado al diseño de un sistema de producción que pueda entregar un producto hecho a la medida, de forma instantánea luego de un pedido, sin mantener inventarios intermedios." (Gregory Howell[iv] – 1999)

En resumen, el Lean Production busca:

- Eliminar todo aquello que no produce valor para el cliente final.
- Organizar la producción como un flujo continuo.

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[i] Taichi Ohno, pionero de la implantación del Justo a Tiempo (JAT) en Toyota Motors. Nació en Manchuria en 1912. Se graduó en 1932 en el departamento de tecnología mecánica del Instituto Técnico de Nagoya y entró a trabajar en la planta de hilados y tejidos Toyota. En 1962 lo nombran director general de la planta principal y el JAT se extiende a los procesos de fundación y forjado.

[ii] W. Edwards Deming (1900 – 1993) estadístico y asesor en gestión de la calidad, de origen norteamericano, es conocido principalmente porque ayudó a revitalizar la industria japonesa en los años posteriores a la II Guerra. En la década de 1980 fue un consultor muy solicitado por la industria Norteamericana.

[iii] Calidad Total (Total Quality Managment – TQM), Gestión estratégica para introducir a una conciencia de calidad en todos los procesos organizacionales. Es asegurar la calidad a través de métodos estadísticos. TQM apunta a hacer las cosas bien desde el comienzo, en vez de arreglar los problemas después de su aparición. TQM tiene el objetivo de mejorar la producción y reducir las pérdidas.

[iv] Gregory Howell (USA), Co-fundador y Director Gerente de Lean Construction Institute, USA. Socio del Lean Project Consulting, Ketchum Idazo, USA.

- Perfeccionar el producto y crear un flujo de trabajo confiable, a través de la disminución de la variabilidad en el flujo, la distribución adecuada de la información y la descentralización de la toma de decisiones.
- Alcanzar la perfección: entregando bajo pedido un producto que satisfaga los requerimientos del cliente y evitando el inventario.

3.1. Lean Construction

"Lean Construction" o "Construcción Sin Pérdidas" es una filosofía de gestión de la producción, que tiene por objetivo el aumento de la productividad teniendo su enfoque en satisfacer las necesidades de los clientes. Ha sido desarrollada como resultado de la aplicación de ideas del Lean Production a la construcción.

Según el Lean Construction Institute[v] (LCI), Lean Construction se extiende sobre los objetivos del Lean Production, los cuales son maximizar el valor para el cliente y minimizar las pérdidas. Para ello define técnicas específicas que son aplicadas en un nuevo proceso de entrega de proyectos. Dentro de estas técnicas podemos mencionar:

- El producto y el proceso de producción son diseñados de manera conjunta para definir y alcanzar, de una mejor manera, los objetivos del cliente.
- El trabajo es estructurado a través del proceso de diseño del proyecto para maximizar el valor y reducir las pérdidas.
- Los esfuerzos para manejar y mejorar los rendimientos específicos son dirigidos a la mejora del rendimiento total del proyecto, debido a que este último logra ser más importante que la reducción del costo o el aumento de la velocidad en alguna actividad específica.
- El concepto de control es redefinido como "hacer que las cosas pasen", en lugar de un "monitoreo de resultados". El rendimiento de los sistemas de planeamiento y control son medidos y mejorados.

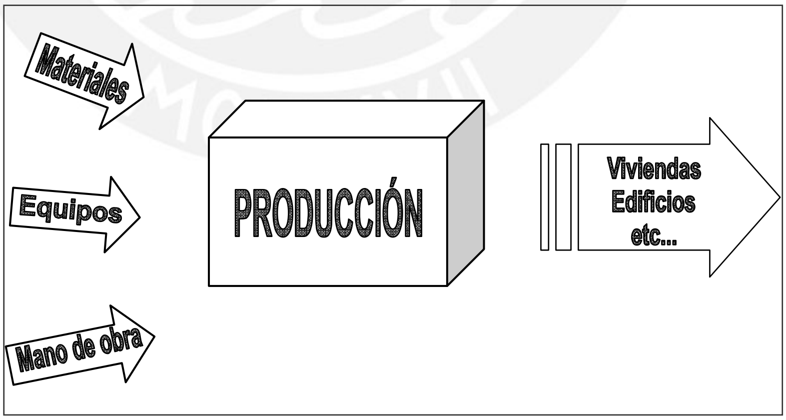
[v] El Lean Construction Institute es una corporación sin fines de lucro que fue fundada en Agosto de 1997. Sus miembros están dedicados a realizar investigaciones para desarrollar conocimientos acerca de proyectos basados en la gestión de la producción, diseño, ingeniería y construcción.

La teoría y método del Lean Construction tienen su base en dos propuestas. La primera propuesta, de Lauri Kokela[vi], señala que la construcción debe ser una producción basada en el concepto Transformación – Flujo – Valor (TFV). La segunda, cuyos autores son Glenn Ballard[vii] y Gregory Howell[viii], introduce el método de control de la producción del último planificador (Last Planner).

3.2. La filosofía de producción Transformación-Flujo-Valor

En la gestión de la construcción a partir del siglo XX se han considerado y puesto en práctica tres conceptos de producción: la transformación, el flujo y el valor.
El primer concepto considera a la producción como la transformación a partir de la entrada de insumos (input) hacia la salida de productos (output) tras la finalización del proceso. Dicho proceso se descompone a su vez en otras transformaciones, hasta llegar a las transformaciones elementales, las cuales deben ser realizadas de la manera más eficiente posible para que el proceso global también sea eficiente.

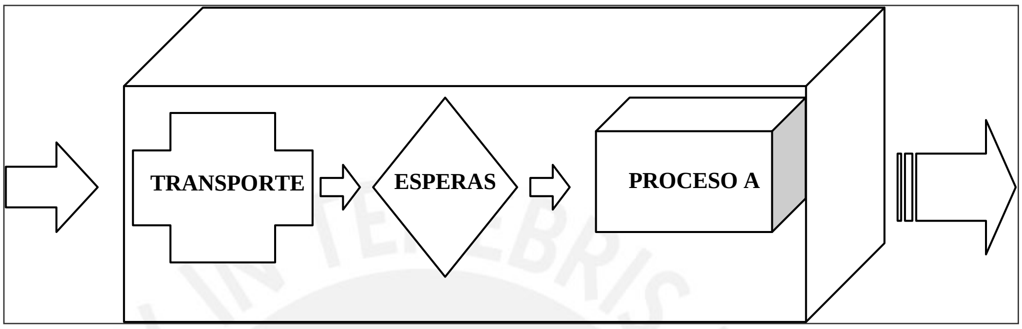
Este modelo ha sido el más usado para analizar la producción en la construcción y se esquematiza de la siguiente manera:



Cuadro Nº1 : *Esquema de la producción en la construcción*

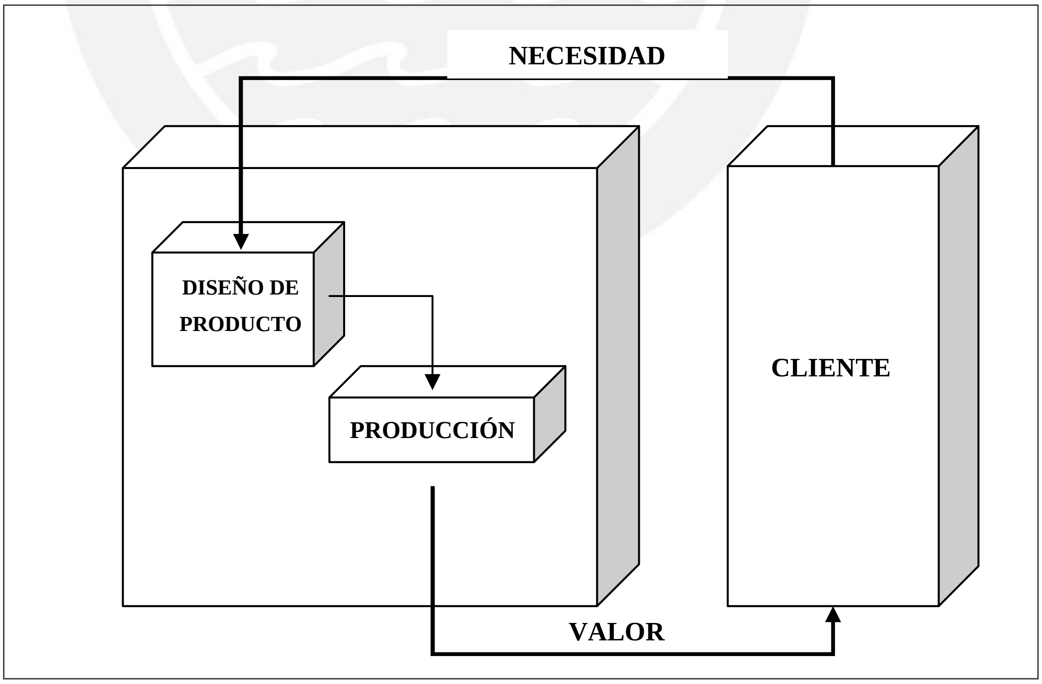
[vi] Laura Koskela profesor finlandés, quién estableció los principios de producción en construcción, tomando como referencia la teoría Lean Production, basada en el modelo de producción japonés.
[vii] Glenn Ballard (USA), Profesor de la Universidad de California, Berkeley, Director de Investigaciones del Lean Construction Institute, y Director en Strategic Project Solutions, Inc. Creador del sistema Last Planner para control de producción.
[viii] Gregory Howell (USA), Co-fundador y Director Gerente del Lean Construction Institute, USA. Socio del Lean Project Consulting, Ketchum Idazo, USA.

El segundo concepto es el modelo de flujos en el cual la producción es concebida como un flujo de procesos, materiales e información, donde adicionalmente a la transformación también se considera la existencia de esperas, inspecciones, transportes y trabajo rehecho.



Cuadro Nº2 : *Esquema del concepto de flujos*

El tercer concepto considera la producción como un proceso para identificar las necesidades del cliente. Estas necesidades se trasladan a un diseño del producto y son alcanzadas a través de la reestructuración del mismo.



Cuadro Nº3 : *Esquema de la producción como generadora de valor*

La nueva filosofía de producción Transformación-Flujo-Valor, desarrollada por Ph.D. Lauri Koskela en 1992, integra los tres conceptos de producción antes descritos dentro de las siguientes características:

- Reducción de las actividades que no agregan valor para el cliente.
- Incremento del valor de la producción, a través de una consideración sistemática de los requerimientos del cliente.
- Reducción de la variabilidad en los procesos de producción.
- Reducción de tiempos en los ciclos de producción.
- Simplificación de los procesos de producción mediante la reducción de pasos, partes y relaciones.
- Incremento de la flexibilidad del producto terminado.
- Incremento de la transparencia de los procesos.
- Enfoque en el control de procesos complejos.
- Introducción de nuevos procesos para la mejora continúa.
- Balance entre la optimización de los flujos de los procesos y la optimización de las conversiones.
- Comparaciones periódicas dentro y fuera de la empresa (benchmarking).

3.3. Last Planner

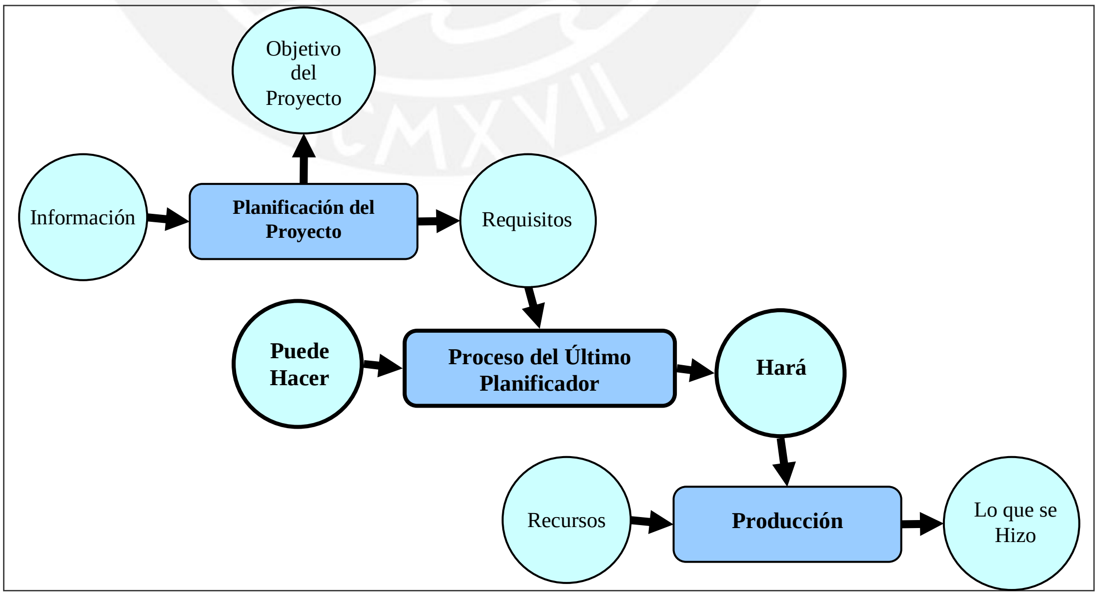
El desarrollo de todo proyecto, contempla la realización de una planificación maestra basada en supuestos y condiciones ideales, en base a las cuales se elabora el presupuesto de obra. Al momento que la construcción del proyecto inicia, surgen imprevistos y variaciones de las condiciones iniciales asumidas, las cuales generan retrasos y costos adicionales si no son detectados y controlados a tiempo.

Ante esta situación surge el sistema de control de la producción del último planificador (Last Planner) que fue desarrollado por Ph.D. Glenn Ballard y P.E. M.S.C.E. Greg Howell durante la segunda mitad de la década de los noventas. El objetivo principal de este sistema es mejorar la confiabilidad en la planificación, por medio de un adecuado control del flujo de la producción. Donde el concepto de control es considerado como “la ejecución de acciones necesarias para que la planificación se cumpla", a diferencia del concepto tradicional, en donde se entendía al control como el "monitoreo de los resultados".

Last Planner hace referencia a la persona o grupo de personas, que se encarga de la definición final y asignación del trabajo. Esta planificación tiene la particularidad de ser utilizada para la asignación de tareas y no para la generación de alguna planificación posterior. Para definir esta asignación del trabajo, tal como en el método tradicional, se toma en cuenta la planificación maestra, considerando además la capacidad de producción real de la cual se dispone. Pero para poder definir adecuadamente esta capacidad de producción real, se debe considerar la variabilidad de los procesos, lo cual genera incertidumbre sobre el conocimiento de la situación en la que se encontrará el proyecto luego de un largo periodo de tiempo.

Por ello la tarea del último planificador se realiza como una planificación a corto plazo, por lo general una semana, en la cual la incertidumbre es menor.

Esta teoría se puede ver de una mejor manera en la siguiente ilustración:



Cuadro N°4 : *Esquema del Last Planner*

3.4. Look Ahead Planning

Look Ahead Planning (LAP) es una herramienta de planificación de jerarquía media, basada en la planificación maestra, en la cual se genera información para la realización de una planificación a corto plazo, que ayuda al control de la asignación de trabajo.

Como producto de la aplicación del LAP se obtiene el Look Ahead Schedule que es un cronograma comúnmente utilizado en la industria de la construcción el cual típicamente resalta lo que se debe realizar durante el periodo analizado.

Según Ph.D. Glenn Ballard el proceso del Look Ahead aplicado dentro del marco del sistema del último planificador permite que este cumpla las siguientes funciones:

- Moldear la secuencia del flujo de trabajo.
- Emparejar el flujo de trabajo con la capacidad.
- Descomponer la planificación maestra en paquetes de actividades de trabajo y operaciones.
- Mantener un inventario de trabajo listo para realizarse.
- Actualizar y revisar los cronogramas de mayor jerarquía según sea necesario.

Las funciones anteriormente descritas son alcanzadas a través de la realización de los siguientes procesos:

- <u>Definición de actividades:</u> Las actividades definidas en la planificación maestra se descomponen identificando las asignaciones, las cuales son actividades de un tamaño apropiado para ser incluidas en un plan de trabajo semanal.

- Análisis de restricciones: Para cada una de las asignaciones identificadas se realiza el análisis de restricciones en el cual se listan los recursos y restricciones en general necesarios para que la asignación este lista para realizarse.

- Asignación del trabajo según el criterio de "jalar" (pull): se realiza en función a la condición de la planificación, cuando se requiere, emparejando el trabajo que se debe de realizar con el trabajo que se puede realizar.

3.5. Porcentaje de Planificación Completa (PPC)

El control dentro de la teoría del Lean Construction se ha redefinido como la acción de "asegurarse que las cosas sucedan", lo que implica ejecutar las acciones descritas anteriormente en las herramientas Last Planner y Look Ahead Planning. Este control se ejerce con anterioridad a la ejecución con el objetivo de aumentar la confiabilidad de las asignaciones.

De forma adicional al control planteado anteriormente por Ph.D. Glenn Ballard, se propone dentro del sistema Last Planner una herramienta de "control tradicional" denominada Porcentaje de Planificación Completa (PPC). El PPC es una herramienta que ayuda al control de la producción; el cual evalúa la planificación. A diferencia de las herramientas anteriores, esta se realiza en un momento posterior a la ejecución.

Esta herramienta es calculada dividiendo el número de actividades completadas entre el número total de actividades planeadas, expresado como porcentaje. Luego de la ejecución de las actividades en campo, se genera un registro en el cual se indica que actividades planificadas no han sido cumplidas, indicando también los motivos por los cuales ha sucedido el incumplimiento.

El PPC es una herramienta de útil ayuda a la identificación de restricciones, que facilita el mejoramiento continuo de la confiabilidad de la planificación y como consecuencia el desempeño del proyecto.

4. SUBCONTRATOS EN LA CONSTRUCCION

En nuestro medio muchas de las empresas que se encuentran desarrollando proyectos de edificaciones han optado por la opción de subcontratar actividades ya sea para asegurar costos o porque el subcontratista cuenta con mano de obra especializada para llevar a cabo una determinada labor.

Esta tendencia no sólo se produce aquí ya que en países vecinos como Brasil y Chile se ha venido repitiendo el mismo patrón durantes los últimos años, tendencia que viene aumentando cada vez más.

Para poder entender las ventajas y desventajas que se producen al subcontratar, es necesario definir algunos términos, para lo cual nos basaremos en un documento redactado por Julio Y. Shimizu y Francisco F. Cardoso[ix].

4.1. Integración Vertical

Integración vertical involucra una variedad de decisiones referentes a si la compañía debe producir los servicios que requiere por ella misma o, por el contrario, debe adquirirlos de alguna otra empresa.

La principal cuestión es hasta que punto la empresa es directamente responsable de producir todo lo que necesita. Así, si la compañía decide adquirir algunos productos de otra empresa para elaborar los suyos, lo ideal sería lograr el manejo eficiente de dicha relación con la otra empresa.

Las principales ventajas competitivas atribuidas a la integración vertical incluyen:

- La mejora de las actividades de marketing y de tecnología inteligente.
- Mayores controles sobre el entorno.

[ix] "Subcontracting and Cooperation Network in Building Construction: A Literature Rewiew" Expuesto en Agosto del 2002 en Gramado, Brazil por motivo de la conferencia anual organizada por el IGLC (Internacional Group for Lean Construction).

- Mayor eficiencia en la transferencia de la información. Este beneficio es importante destacar ya que el poseer información implica un gran poder tanto para negociar como para la gestión de inventarios.

- Disminución de costos por el crecimiento en la curva de aprendizaje: los gastos de asesoramiento técnico, por ejemplo, disminuyen en el tiempo como consecuencia de las habilidades adquiridas por los productores. Además, los costos de transacción son menores por el mayor conocimiento de la negociación y la reducción de los incumplimientos contractuales.

Aunque todos estos beneficios pueden proporcionar una ventaja competitiva, esta ventaja no tiene el carácter de permanente.
Aspectos negativos de la existencia de integración vertical son los requerimientos de capital, desequilibrio en los rendimientos, reducción de la flexibilidad o menor especialización en las actividades subcontratadas.

El desarrollo adecuado de las estrategias de integración, según Krippachne (1992), requiere de las siguientes acciones:

- Evitar el desarrollo interno de aquellas capacidades que pueden ser satisfechas por agentes externos.

- Desarrollar buenas relaciones con los grupos de subcontratistas y proveedores con los que se trabaja.

- Apelar a otras empresas precalificadas para monitorear las condiciones de los precios del mercado y tecnología.

- Reducir la cantidad de trabajo realizado con recursos propios, desintegrándose en cierto grado, principalmente en aquellas actividades con poco margen de ganancia.

- Tener presente que cualquiera sea la estrategia adoptada, ésta debe ser constantemente revisada.

4.2. Partnering

Es una relación a largo plazo en la que las partes involucradas realizan una inversión significativa con el fin de obtener algún beneficio o alguna ventaja competitiva conjunta.
Mientras que el lean se enfoca en el aseguramiento de la confiabilidad en los flujos, el partnering se enfoca en forjar un mayor grado de confianza. Confianza es aquella actitud humana que aflora cuando existe confiabilidad.

El CII[x] (Conctruction Industry Institute) ofrece la siguiente definición de partnering:
"Partnering es una relación a largo plazo entre dos o más organizaciones con el propósito de alcanzar objetivos específicos de negocio, por medio de la maximización de la efectividad de los recursos de los participantes. Esto requiere cambiar la forma tradicional en que se llevan las relaciones entre participantes de un proyecto por una cultura compartida que no toma en cuenta las fronteras organizacionales. Dicha relación se basa en confianza, dedicación hacia metas comunes, y comprensión de las expectativas y valores individuales. Los beneficios esperados incluyen el aumento de la eficiencia y la efectividad en temas de costos, fomentar las oportunidades para la innovación, y la mejora continua de la calidad de los productos y de los servicios."

Según Bresnen y Marshall (2000), partnering apunta a reducir la adversalidad, la cual parece ser típico en la industria y la causante de disipar intentos previos de establecer mejores relaciones de integración y cooperación entre las partes contractuales.

Partnering es una relación entre organizaciones en donde:

[x] CII fue fundada en 1983 para mejorar la efectividad de costos (cost effectiveness) de las industrias más grandes de las naciones. Los miembros, quienes representan a distintas empresas y contratistas, consideran que muchos de los problemas que limitan la efectividad de costos son comunes, y que el mayor beneficio se puede obtener en un ambiente de cooperación con beneficios compartidos por toda la industria de la construcción.

- Todas las partes buscan soluciones a los problemas que sean mutuamente beneficiosas al final del proyecto.

- Confianza y honestidad son una parte normal de la relación. El intercambio de ideas y problemas sin temor a represión fomenta la rápida resolución de dificultades y la mejora de la eficiencia organizacional.

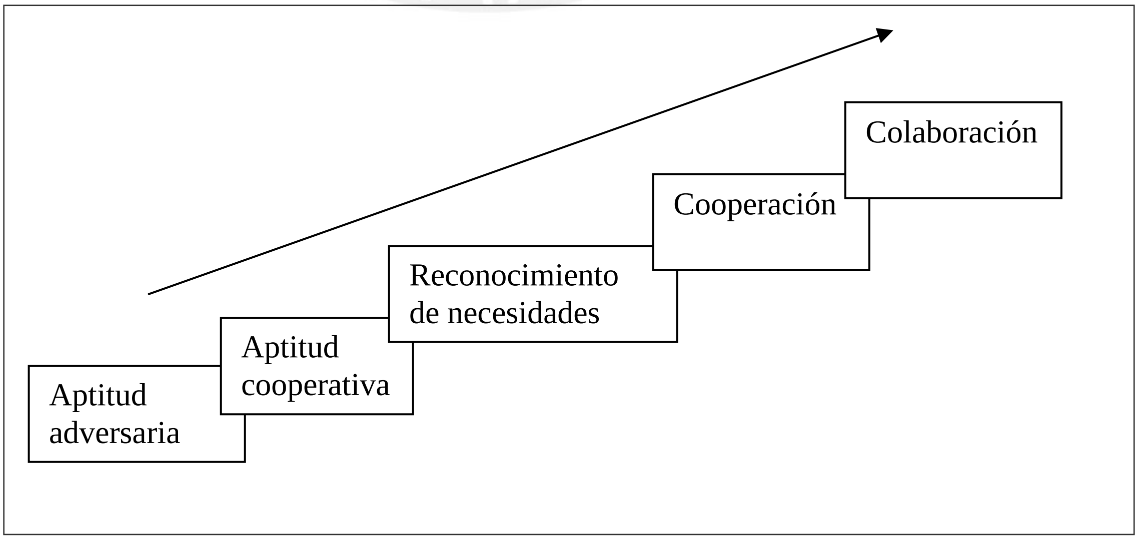
- Existe un ambiente que promueve la disminución de costos y el aumento de la utilidad, lo cual es muy sano para la relación.

- Se fomenta la innovación. Se debe de cambiar la mentalidad “No es mi idea, entonces no es buena” por “Todos nos beneficiamos de la mejora en la eficiencia y de la innovación”:

- Cada participante es conciente de las necesidades y preocupaciones de los otros partidos. No se toman acciones sin considerar quién es afectado y como es afectado.

- Se mejora el desempeño total.

El cambio alcanzado a través de la aplicación de partnering atravesará por diversas fases antes de alcanzar su objetivo final de colaboración. Estas etapas de cambio son las siguientes:



Cuadro Nº5 : *Esquema de las etapas del partening*

El mayor beneficio del partnering se va a lograr cuando todos los involucrados en un proyecto (incluyendo a los proyectistas, los contratistas, subcontratistas, proveedores y hasta al cliente y los agentes reguladores del proyecto) no sólo cooperen sino que colaboren. Colaboración involucra reconocer las necesidades y objetivos de todos los involucrados.

Los libros "Trusting the Team[xi]" y "Seven Pillars of Partnering[xii]" demuestran que donde se aplica partnering a lo largo de varios proyectos se obtiene hasta un 30% de ahorro, y que en algunos casos se puede obtener 50 % de reducción en costos y hasta 80% en ahorro en tiempo.

A continuación se detallan una serie de factores para llevar a cabo una relación de partnering exitosa:

- Desarrollo de la confianza
- Trabajo en equipo
- Compromiso
- La necesidad de forjar compromisos más sólidos
- Recalcar la importancia del individuo
- El movimiento estratégico del personal clave
- La necesidad de una comunicación abierta y flexible
- Evaluación continúa.

Entre las ventajas con las que se cuenta producto de la aplicación del partnering se pueden mencionar: reducción de costos, disminución del tiempo de entrega del proyecto, mejora en la calidad de la construcción, desarrollo de una mejor atmósfera de trabajo y fomento del aprendizaje organizacional.

En la literatura desarrollada referente al tema se encuentran 2 tipos de partnering, clasificadas según la duración de la cooperación entre participantes. Los tipos distinguidos son los siguientes:

- Project Partnering (Partnering por proyecto) es aquella relación que se produce durante la ejecución de un proyecto. Si las empresas relacionadas no vuelven a

[xi] Bennett, J. & Jayes
[xii] John Bennett and Sarah Jayes

trabajar en alguna otra ocasión, todo el aprendizaje obtenido durante el proyecto se pierde. Hay que tener en cuenta que este tipo de alianza por proyecto puede derivar en un tipo de alianza estratégica.

- Strategic Partnering (Partnering Estratégico) es una relación con un alto grado de cooperación entre los participantes que se extiende a largo plazo a través de varios proyectos. En este caso lo aprendido como equipo permite que se obtengan mayores beneficios ya que la información obtenida cumple su ciclo y retroalimenta el sistema.

4.3. Subcontratos

La industria de la construcción depende de subcontratistas y de proveedores de materiales y equipos de construcción. Dado el enfoque tradicional que se aplica en la industria de la construcción, los subcontratistas se encuentran en una posición de subordinación frente a las contratistas. De este modo, la relación entre ambos suele ser tensa y adversaria.

Según Beardworth (1988), el subcontrato ha sido presentado como una alternativa organizacional para algunas actividades económicas. Dado que las empresas se están descentralizando cada vez más, el subcontrato se asienta con mayor intensidad en la organización de trabajo.

Para Pagnani (1989) el subcontrato es una relación económica – legal entre dos agentes, en la cual la característica fundamental son la substitución y la subordinación. Por substitución se entiende que el subcontratista asume el riesgo técnico y financiero de llevar a cabo las operaciones, en lugar del contratista. La subordinación implica que el subcontratista debe seguir la dirección dada por el contratista, radicando en ello su dependencia.

Veltz (2000) recalca que las empresas no necesitan tener el control de toda ruta de valor, pudiendo dar a terceros aquellas actividades no estratégicas con la finalidad de reducir costos.

Tomado de un estudio realizado por Shimizu y Cardosa en el año 2002 en Brasil, se presenta a continuación el siguiente cuadro en donde se indican algunos aspectos de los subcontratos en edificaciones:

ASPECTOS	COMENTARIOS
Flexibilidad	La subcontratación parece ser una respuesta a las incertidumbre del mercado
Calidad	La subcontratación, por un lado, puede promover la calidad de un producto porque usa mano de obra especializada y, por otro lado, puede empeorarla porque conlleva a problemas de control y coordinación.
Costo	El costo directo disminuye, mientras que los costos de transacción [xiii]aumentan. El costo directo es menor porque la subcontratación elimina el mantenimiento del equipo y la subutilización de la mano de obra. Los costos de transacción aumentan porque cada nueva negociación involucra proposiciones de los subcontratistas.
Productividad	La subcontratación tiende a unir al trabajador con la firma subcontratista. Esto resulta en una mayor productividad en la mano de obra debido a la continuidad y al aprendizaje. Fácil acceso a equipos especializados y constante capacitación también elevan la productividad.
Controles	Controlar la calidad del trabajo es difícil, debido a la alta cantidad de organizaciones independientes en el sitio.
Planeamiento	La intensiva subcontratación de la mano de obra hace difícil el proceso de planeamiento. Peor aún, los conflictos de intereses pueden intervenir negativamente con la programación de actividades.
Tecnología	La inestabilidad del mercado conlleva a las firmas contratistas a no establecer acuerdos estables con los subcontratistas, impidiendo la transferencia de tecnologías.
Capacitación	El contratista tiende a derivar la responsabilidad de la capacitación a los subcontratistas, pero generalmente ellos no son aptos para llevarla a cabo, debido a problemas financieros y el tiempo insuficiente para entrenar.
Seguridad	La responsabilidad final de la seguridad recae en la compañía contratista, así como también la implementación de un programa de seguridad y la supervisión del subcontratista. El desinterés del contratista en invertir en programas de seguridad para trabajadores no permanentes y desconocidos, y la falta de familiaridad de los trabajadores con el ambiente de trabajo empeoran el problema.
Consumo de materiales	Los subcontratistas pueden aumentar el consumo de materiales, ya que tienden a finalizar el trabajo tan rápido como sea posible, sin controlar el uso de los materiales.

Adaptado del texto "Subcontrating and cooperation network in building construction: a literature review"

Tabla Nº1 : *Principales aspectos de los Subcontratos*

Según Welling y Kamann (2001) la industria de la construcción se caracteriza por ser de comportamiento oportunista y por la falta de integración vertical. Esto conlleva a que la relación entre contratista y subcontratistas sea tensa y adversa, en donde se desarrolla una tendencia denominada de suma cero, en donde una de las partes gana a expensas de la otra.

[xiii] Son aquellos costos, distintos del precio del dinero, en que se incurre tanto antes, durante y después de que se compra un bien o un servicio. El costo de la información, de la negociación y de la decisión, de la verificación de que se cumplan los acuerdos establecidos son algunos de los más importantes costos de transacción.
Algunos asumen que la información y otros costos de transacción son cero. Pero la verdad es que el beneficio de la entidad con la que negociamos debe ser lo suficientemente grande como para cubrir el costo de transacción que asume.

Según un estudio realizado por Dainty et al (2001) y publicado posteriormente en un documento realizado por Sergio Maturana, Luis Alarcón y Mladen Vraslovic en el año 2004, se identificaron algunos puntos considerados por los subcontratistas como barreras para la integración:

1. Asuntos relacionados con el costo: debido a la tendencia competitiva basada simplemente en el precio, se ha generado una relación adversa que se ve reflejada en problemas de pagos.

2. Asuntos relacionados con la programación y el tiempo: tales como creación de falsas expectativas por parte del contratista y programaciones irreales.

3. Asuntos relacionados con la calidad de la información: tales como una deficiente calidad de la información así como una administración inadecuada por parte del contratista.

4. Asuntos relacionadas con la actitud, tales como la arrogancia por parte del contratista, exclusión del subcontratista en la parte inicial del proyecto, falta de premios por un buen desempeño, prácticas de administración de campo deficientes y falta de comprensión de los problemas de los subcontratistas.

4.4. Acercamiento a la colaboración, Lean Construction y Comunicación

Dado que el acercamiento al lean construction apunta a la reducción de perdidas y al mismo tiempo a la generación de valor al proceso constructivo, y que las iniciativas para la aplicación del Supply Chain Management[xiv] consideran métodos como Partnering, es un hecho que la eficiente aplicación del lean construction va a depender en gran medida del grado de compromiso de las empresas contratistas por disminuir el costo de transacción a través de una administración adecuada de sus subcontratos.

[xiv] Es la gestión de toda la cadena de valor agregado, desde el proveedor de manufactura hasta el Distribuidor y el comprador final. Tiene tres objetivos: Reducir el inventario, incrementar la velocidad de transacción a través del intercambio de información en tiempo real, y el incremento de las ventas alcanzando los requerimientos del cliente de forma más eficiente.

Cuando se implementa un acercamiento colaborativo, la coordinación debe ser alcanzada a través de la comunicación. Esta comunicación ha sido definida por March y Simon (1958) como “comunicación por medio de la retroalimentación”. Vrijhoer et al (2001) describe cómo la comunicación en las organizaciones puede ser entendida desde dos puntos de vista: la perspectiva de la información, que implica el intercambio de hechos, opiniones y descripciones; y la perspectiva organizacional, que incluye nociones de obligación, responsabilidad, acciones que fomenten la comunicación, etc.

5. TIPO DE ESTRUCTURA

En el presente documento se realizará una investigación acerca de la relación de la productividad con el tipo de estructura.

Sin embargo, es necesario despejar la primera duda que surge al juntar ambos temas: ¿Es posible comparar la productividad, valor obtenido durante la construcción del proyecto, con el tipo de estructura, el cual es definido con el Ingeniero Estructural en la etapa de diseño del proyecto?

La respuesta, como debe imaginarse, es afirmativa. Se puede comparar la productividad con el tipo de estructura; pero no con los planos hechos por el Ingeniero Estructural, si no con el procedimiento constructivo asociado al tipo de estructura que se le ha dado al proyecto.

Por lo tanto, se definirá el concepto de constructabilidad, el cual debe aplicarse desde la concepción del proyecto; seguido de una explicación más honda de la relación de los procesos constructivos con el tipo de estructura.

5.1. Constructability (Constructabilidad)

Según la filosofía del Lean Construction, existe una metodología basada en la retroalimentación que favorece a la productividad desde los inicios del proyecto, es decir, desde la preparación de los planos de arquitectura.

Esta metodología consiste en la aplicación de las experiencias y conocimientos de construcción adquiridos durante los proyectos pasados, los cuales deben ser usados de forma óptima en la planificación, en el diseño, en las adquisiciones y en el manejo de las operaciones de construcción; aplicando así lo que el Construction Industry Institute (CII) definió como “Constructability” (Constructabilidad).

La aplicación de la Constructabilidad trae como consecuencias prácticas, las que podemos citar a continuación:

- Los proveedores y subcontratistas participan durante la etapa de diseño.

- La experiencia en proyectos terminados alimenta a los proyectos siguientes.

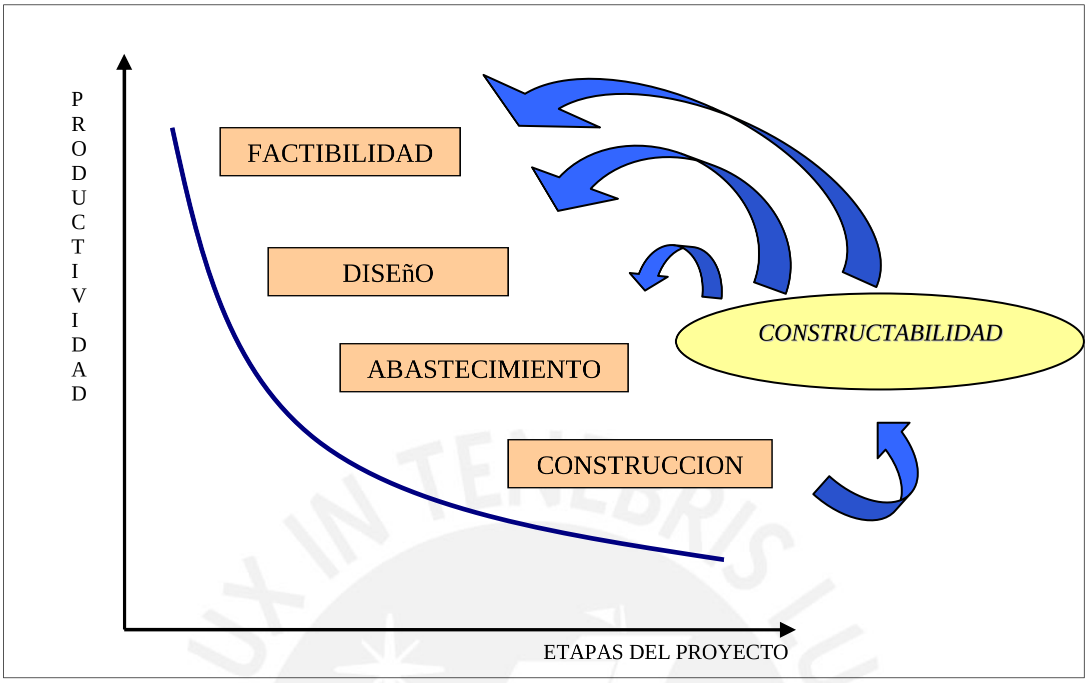
- La calidad es fundamental en el proceso de diseño. Los defectos deben ser subsanados antes de iniciarse los trabajos de construcción.

- Los diseñadores trabajan junto a los otros participantes en el proceso del proyecto. Ellos deben entender mejor el proceso constructivo y cómo sus habilidades creativas y analíticas pueden ayudar a mejorarlo, mediante sus diseños.

- Los diseñadores consideran todo el costo de vida incluyendo los costos de consumo de energía, mantenimiento y resanes; los cuales también inciden en el proyecto.

- Los clientes también aceptan sus responsabilidades para el diseño efectivo. Es común que presionen a los proyectistas para que puedan tener su producto incluso antes del tiempo establecido.

La aplicación de la constructabilidad se puede esquematizar de la siguiente manera:



Cuadro Nº6 : *Esquema del Concepto de Constructabilidad*

Por ejemplo, al momento de preparar el diseño estructural aplicando el concepto de constructabilidad, se debería poner énfasis en los siguientes puntos:

- Considerar la distribución y sentido de las losas aligeradas o macizas, a fin de facilitar los cortes de vaciado.

- Coordinar con los ingenieros de las otras especialidades a fin de no generar congestionamiento de acero, tuberías, etc.; o para considerar las pérdidas de área efectiva en los elementos estructurales debido a la presencia de las tuberías

5.2. Procesos constructivos y Sistemas Estructurales

La Norma Peruana clasifica a las edificaciones según los materiales usados y el sistema de estructuración sismorresistente predominante en cada dirección.

Para la actual investigación nos hemos basado en la clasificación de los sistemas estructurales de dicha norma y hemos asociado cada subclase al procedimiento constructivo común a cada sistema. Cabe resaltar que no se ha considerado el tipo de cimentación de la estructura (zapatas aisladas, combinadas, platea de cimentación, etc.) ni el diafragma rígido común a la edificación (losas aligeradas, macizas, armadas en dos sentidos, etc.).

Por lo tanto, tenemos:

A. Albañilería armada o confinada

La albañilería confinada es aquella reforzada con elementos de concreto armado en todo su perímetro, vaciado posteriormente a la construcción de la albañilería. Básicamente, se coloca primero el acero en las columnas de confinamiento, se realiza el levantamiento del muro de ladrillo King Kong luego de vaciados los cimientos corridos, hasta llegar al fondo de la viga de confinamiento. Luego se encofra con madera las columnas de confinamiento (debido a la poca densidad de columnas en este tipo de proyecto), y se realiza el vaciado de las columnas, normalmente con concreto hecho en obra. La viga de confinamiento se arma, encofra y vacía monolíticamente con el techo.

La albañilería armada es aquella reforzada interiormente con varillas de acero distribuidas vertical y horizontalmente e integrada mediante concreto líquido (grout), de tal manera que los diferentes componentes actúen conjuntamente para resistir los esfuerzos.

B. Pórticos

Es el sistema estructural basado en columnas y vigas de concreto armado. La función estructural es cumplida casi en su totalidad por las columnas de dichos pórticos.

Las secciones de las columnas son mayores que las columnas de confinamiento, por lo tanto se emplea tanto encofrado de madera como de acero, dependiendo de la densidad de columnas. El concreto puede ser hecho en obra como premezclado.

Una vez finalizado el desencofrado de los elementos estructurales, se puede levantar muros de separación o tabiques, los cuales son de ladrillo pandereta, por lo general.

C. Sistema dual

Es aquel que combina pórticos y muros de concreto (placas). Las acciones sísmicas son resistidas, en su mayoría, por los muros de concreto; mientras que los pórticos toman alrededor del 25% del cortante sísmico de la base de la edificación.

Este sistema involucra placas y columnas, de modo que puede llegar a ser recomendable el uso de encofrados metálicos, más no estrictamente necesaria. El uso de concreto premezclado o hecho en obra depende de la secuencia constructiva programada por el ingeniero responsable de la obra.

D. Muros estructurales

Los muros estructurales o placas son elementos de concreto armado de mayores dimensiones que una columna. Se dice que es un sistema de Muros estructurales, cuando estos toman más del 80% del cortante sísmico en la base de la edificación.

En cuanto a proceso constructivo, es muy similar al anterior.

E. Muros de ductilidad limitada

Sistema en el cual todos los muros son portantes y de concreto armado, lo cual permite que tengan bajos espesores.

Actualmente se emplea en edificios de construcción masiva, en los cuales el encofrado metálico y el concreto premezclado son los insumos utilizados por excelencia.

Dependiendo del tipo de encofrado metálico, se puede realizar el vaciado monolítico de la estructura (muros y losa) o se puede seguir la secuencia común, es decir, primero el vaciado de muros y luego el de losas.

iii. METODOLOGIA DEL TRABAJO

En esta sección se describen las herramientas empleadas y los criterios de clasificación de las actividades. Es importante señalar que el criterio empleado en esta tesis difiere del empleado hace 5 años, motivo por el cual la toma de datos se hizo de dos maneras: de la forma como se detalla en este capítulo y de la forma como se realizó en el 2000 con el fin de poder realizar la comparación.

1. MUESTRA ANALIZADA

En un principio, y ante la incertidumbre de los resultados a obtener, se demostró que serían necesarias 50 obras para nuestro análisis. Sin embargo, de acuerdo a los resultados obtenidos, se determinó que con 26 obras teníamos un resultado con un 95% de confiabilidad y un error menor al 5%. La justificación a esta afirmación se encuentra en el Anexo 01.

2. DEFINICION DE LAS HERRAMIENTAS

Se usaron las siguientes herramientas:

2.1. Nivel general de actividad de obra (NGO)

Es un indicador que representa el nivel de productividad del personal de la obra en general. Éste indicador especifica la ocupación del tiempo de los trabajadores de toda la obra en promedio, clasificando el tipo de trabajo en productivo (TP), contributorio (TC) y no contributorio (TNC).

2.2. Formato Identificación de obra (FIO)

Se realizó sólo a los Residentes de las obra visitadas, y tiene como finalidad la de obtener la información necesaria para clasificar la obra en los tipos indicados.

2.3. Formato de encuestas al personal técnico y administrativo de obra (FEPETA)

Se realizaron encuestas al personal que participa en la planificación de la obra con el fin de clasificarla en función de los dos criterios indicados en los objetivos de la tesis.

2.4. Formato de encuestas al personal obrero (FEDOC):

Se realizaron encuestas a los obreros con el fin de identificar los principales problemas con respecto a los recursos y a la comunicación en obra.

2.5. Entrevista a Subcontratistas y Proveedores:

Se realizaron entrevistas a los subcontratistas y proveedores con la finalidad de conocer sus versiones y opiniones respecto a los principales problemas que ocurren en obra.

3. CRITERIOS Y PROCEDIMIENTOS DE LA TOMA DE DATOS

3.1. Del Tipo de trabajo

Se decidió dividir el trabajo en tres tipos, los cuales serán explicados a continuación:

3.1.1. <u>Trabajo Productivo (TP):</u>

Es el trabajo que aporta de forma directa a la producción.
Dentro de las actividades clasificadas como productivas (P) consideramos, según la partida a la que pertenecen, las siguientes:

- *Concreto* : Vaciado, vibrado o chuseado, acomodo de la mezcla con lampa y dar acabado a la superficie (caso de losas).

- *Acero* : Colocación y acomodo de barras de acero, atortolado de mallas y refuerzos, armado de elementos estructurales fuera de sitio (para transportar y colocar columnas o vigas ya armadas).

- *Encofrado*: Colocado de paneles de madera o metálicos, puntales y demás elementos; reforzamiento del encofrado con grapas, alambre o clavos, desencofrado.

- *Albañilería*: Colocación mortero en junta vertical y/u horizontal, colocación de ladrillos y mechas de acero.

- *Tarrajeo* : Pañeteado, paleteado, regleado de superficie, dar acabado a la superficie (con frotacho, esponja y otros).

Además las actividades de habilitación de materiales también fueron consideras dentro de este rubro, entre las cuales tenemos:

- *Concreto :* Preparación del concreto en obra.

- *Acero :* Cortar y doblar las varillas para darles la forma adecuada de refuerzo, bastones o estribos.

- *Encofrado :* Cortar madera para la preparación de paneles para el encofrado, preparación de paneles de encofrado de madera.

- *Albañilería :* Preparación de mezcla seca de cemento y arena, preparación de mortero, cortar y humedecer ladrillos.

- *Tarrajeo :* Preparación de mezcla seca de cemento y arena, preparación de mortero.

3.1.2. Trabajo Contributorio (TC):

Se define como el trabajo de apoyo que debe ser realizado para que pueda ejecutarse el trabajo productivo. Actividad necesaria, pero que no aporta valor.

De modo explicativo, dentro de las actividades contributorias consideramos el transporte de material y/o herramientas (T), cualquier tipo de medición (M), la limpieza (L), dar o recibir instrucciones (I).

Dentro de las actividades clasificadas como otros contributorios (O) tenemos, según la partida a la que pertenecen, los siguientes:

- *Concreto* : Abastecimiento de los componentes a otros recipientes, sostener los recipientes.
- *Acero* : Sostener una barra para que otro la atortole, marcar con tiza las barras y encofrados, armado de andamios.
- *Encofrado*: Sostener el encofrado (paneles, puntales, etc.) mientras otro lo asegura, armado de andamios.
- *Albañilería*: Remover mortero sobrante, el abastecimiento de mezcla a otro recipiente para el transporte, armado de andamios.
- *Tarrajeo* : Humedecer la pared, colocar y extraer los puntos de referencia, armado de andamios.

3.1.3. <u>Trabajo no contributorio (TNC):</u>

Trabajo que no genera valor y no contribuye a otra actividad; por lo tanto, se considera como actividad de pérdida.

Análogamente, como trabajo no contributorio se considera los viajes sin llevar nada en las manos (V), las esperas del personal (E), ir a los servicios higiénicos (BÑ), descansar (D), rehacer un trabajo (TR), hacer trabajos sin valor (TO) y otros no contributorios (OC).

A fin de uniformizar los criterios de evaluación del trabajo, se realizaron mediciones simultáneas, de un mismo proyecto, entre todos los miembros de grupo de tesis y se comprobaron que los resultados obtenidos eran similares.

Cada medición consta de cinco juegos de datos; y cada juego, de 400 evaluaciones del trabajo. Cada juego de datos se tomó en momentos distintos a lo largo del tiempo que duraba la evaluación de la obra, que por lo general era de 5 días útiles.

El formato de medición del Nivel General de Actividad de Obra se encuentra en el Anexo 02.

En el siguiente cuadro se resumen todas los tipos de trabajos considerados, su condición (TP, TC, TNC) y su codificación:

Trabajo Productivo	**TP**
• Trabajo Productivo	P
• Habilitación de material	HM
Trabajo Contributorio	**TC**
• Transporte de todo	T
• Limpieza de todo	L
• Dar y recibir instrucciones	I
• Mediciones	M
• Otros	O
Trabajo No Contributorio	**TNC**
• Viajes	V
• Esperas	E
• Tiempo Ocioso	TO
• Trabajo Rehecho	TR
• Otro	OT

Tabla Nº2 : *Clasificación y codificación de los trabajos*

3.2. De las Encuestas

Las encuestas estaban orientadas a obtener la información necesaria para clasificar a las empresas dentro de los parámetros que describiremos más adelante.

Básicamente, al Ingeniero Residente se le hacía la encuesta de Identificación de Obra y la de Personal Técnico y Administrativo. Si hubiera otro participante en el proceso de planificación de la obra, también debería responder la encuesta de Personal Técnico y Administrativo.

En el caso del personal obrero, las preguntas estaban orientadas a corroborar la veracidad con la cual se respondían las preguntas relacionadas a la planificación de recursos (En el caso del personal Técnico y Administrativo); puesto que nos enfocábamos en determinar si el obrero tenía tiempos no contributorios (mayormente esperas) debido a una mala planificación.
Los dos formatos anteriormente descritos se pueden observar en el Anexo 02.

3.3. De las Entrevistas

En la relación Contratista – Subcontratista o proveedor; existen dos posiciones bastante diferenciadas y creímos necesario conocer ambas. En el caso del Contratista, las encuestas y las conversaciones durante el periodo de medición nos permitieron conocer sus problemas y necesidades como clientes.
Pero en el caso de los Subcontratistas o Proveedores, el contacto no pudo ser tan frecuente, por lo que se recurrió a pactar sendas entrevistas con varios de ellos, en las cuales se realizaron preguntas respecto a los temas de industrialización y subcontratos, como se puede ver en el Anexo02.

4. EVALUACION DE LA INFORMACION OBTENIDA

La evaluación de los datos obtenidos pasó por el siguiente proceso:

4.1. Etapa de Diagnóstico Individual

En esta etapa se evaluó la productividad de forma cuantitativa, mediante el cálculo de los valores de los indicadores de productividad de modo individual (por cada obra) y la generación de informes para las empresas que nos brindaron su apoyo. Dicho informe contenía el promedio de los datos obtenidos en la obra, su interpretación práctica y algunas observaciones con recomendaciones, las cuales nos ayudarían a determinar cuales son los problemas más frecuentes en las obras.

4.2. Etapa de Diagnóstico Integral

Es la segunda parte de la evaluación cuantitativa, en la cual se parte con los resultados de la etapa individual. En un principio, clasificamos las obras de acuerdo al tipo de estructura y al grado de integración entre los subcontratos y contratistas.

Luego relacionamos su clasificación con en nivel de productividad de cada obra. Por otro lado, determinamos el nivel de productividad de Lima Metropolitana, dentro del ámbito de nuestros alcances.

4.3. Etapa de conclusiones y recomendaciones

En esta etapa interpretamos los resultados obtenidos en las dos etapas predecesoras y generamos nuestras conclusiones y recomendaciones para este trabajo de investigación.

iv. ANALISIS DE RESULTADOS

En esta sección se presenta, en primer lugar, el criterio que se ha optado para clasificar a las obras analizadas. Luego se muestran los resultados obtenidos referentes a productividad, al tipo de estructura y al grado de integración. En esta parte se analiza la similitud o diferencia existente entre nuestros resultados con los obtenidos hace 5 años.

Finalmente, se culmina el capítulo cruzando la información hallada relacionada al tipo de estructura y al grado de integración con nivel de productividad correspondiente.

1. PARAMETROS DE CLASIFICACION

1.1. Según grado de integración de los subcontratos:

Se evaluó el grado de integración de los subcontratos por medio de los siguientes parámetros, propuestos por nosotros, a los cuales se les asignó un puntaje según su importancia:

A. Modo de Elección:

Consideramos como Modo de Elección al conjunto de parámetros por medio de los cuales la Empresa contratista evalúa las propuestas de los distintos subcontratistas a fin de escoger la más adecuada para cerrar el trato.

a) Menor costo

Se refiere a la elección del subcontratista teniendo como única consideración que la propuesta ganadora sea la más barata de todas.

b) Sistema de Evaluación

La elección se realiza a través de un sistema de evaluación, el cual engloba criterios como precio, calidad, trabajos anteriores, etc. además que se analiza el efecto costo – beneficio.

B. Tipo de Contrato

Se refiere al modo de transmisión de las responsabilidades de ambas partes durante la ejecución del proyecto.

a) Informal

Es el convenio en el cual no hay un documento que lo sustente. De modo que es susceptible de modificaciones en cualquier momento y sin respeto a ambas partes. No se puede ejercer ningún tipo de acción legal y puede darse el caso de abusos por parte del contratista.

b) Formal

Es el convenio que tiene un documento escrito, en el cual se indica solamente el metrado a realizar, el plazo a cumplir y el monto de pago fijado. Debido a la poca claridad con que se detalla la tarea a realizar, su interpretación suele ser de forma subjetiva y fácil de malinterpretar.

c) Óptimo

Es el convenio que, además de lo especificado para el escrito, incluye especificaciones de la actividad subcontratada (según el riesgo que aporte el subcontratista). Además, puede incluir un sistema de premios y/o sanciones.

C. Costos

Se centra en determinar quién o quienes son los beneficiados al término del proyecto. Se ha clasificado en dos tipos:

a) Unilateral

Cuando sólo se beneficia una de las partes, mayormente el contratista, pudiendo provocar disminución en el márgen de ganancia, pérdidas o cero utilidades a la otra parte involucrada.

b) Bilateral

Cuando ambas partes salen beneficiadas al término del contrato, habiendo cumplido o superado sus expectativas.

D. Grado de control durante la ejecución del proyecto

Durante la ejecución del proyecto, el contratista ejerce un control sobre los distintos aspectos que engloba la actividad subcontratada. Un alto grado de control no sólo beneficia al contratista sino que a su vez el subcontratista se ve beneficiado ya que se alinea a un procedimiento de trabajo ordenado y eficiente. Dicho control se ha clasificado en tres, según la intensidad del mismo:

a) Control mínimo o no controlado

Cuando no se ejerce ningún control o sólo se centra en el avance del subcontratista. Éste se realiza cada cierto tiempo de forma esporádica.

b) Control mediano

Cuando se realizan controles de avance y calidad constructiva de manera continua durante la ejecución del proyecto.

c) Control máximo

Cuando los controles son diarios o muy frecuentes y, además del avance y calidad constructiva, evalúan temas como costos, productividad, entre otros.

E. Participación en la planificación

La clasificación se centrará en la participación de los subcontratistas durante el proceso de planificación, del modo que se indica a continuación:

a) Activa

Si es que el subcontratista participa en algún tipo de planificación a largo, mediano y corto plazo.

b) Pasiva

Si es que el subcontratista no participa en la planificación. También está incluido en esta categoría el caso en el que el subcontratista se entera del sector de avance al iniciar la jornada laboral.

F. Continuidad

Se refiere a la frecuencia de la participación del subcontratista con la empresa contratista, en el caso de varios proyectos.

a) Nula

Si es que la empresa contratista cambia de subcontratista para cada proyecto.

b) Inicial

En el caso del segundo o tercer proyecto que realiza la empresa con el mismo subcontratista. Es decir, si es que existe una posibilidad de continuidad alta.

c) Alta

En el caso de que el contratista y subcontratista tienen varios proyectos trabajando en conjunto, mas no necesariamente a la vez.

Para realizar la clasificación se le asignó a cada característica un puntaje y se establecieron rangos con la finalidad de ubicar a cada obra en un determinado nivel de integración. El detalle de dicho procedimiento se explica en la sección 2.3.1. (pág. 53)

1.2. Según el tipo de estructura

Se evaluó el tipo de estructura por medio de los siguientes criterios:

CLASIFICACION	PROCESO CONSTRUCTIVO	SISTEMA ESTRUCTURAL
TIPO I	En este tipo se considera el uso de albañilería con función estructural. Es decir, en el caso de la albañilería confinada, primero se debe colocar la armadura de los elementos de confinamiento, luego levantar el muro de ladrillo para finalmente vaciar los elementos de confinamiento. En el caso de la albañilería armada, el propio muro representa el sistema de confinamiento, lo que da como resultado que el muro y la armadura se van levantando al mismo tiempo.	Albañilería armada, albañilería confinada, sistemas mixtos (pórticos y albañilería)
TIPO II	En este tipo se considera el uso de elementos estructurales de concreto, como placas y columnas, los cuales actúan formando pórticos estructurales.	Pórticos, Sistema Dual, Muros estructurales
TIPO III	En este tipo se considera el uso de muros de concreto de espesor delgados como elementos estructurales. Las únicas tabiquerías con los alfeizar de ventanas o parapetos.	Muros de ductilidad limitada o muros de concreto armado hasta de 0.15 m de espesor.

Tabla Nº3 : *Clasificación y codificación del tipo de estructura*

2. PRESENTACION Y ANALISIS DE RESULTADOS

2.1. Relación Productividad año 2000 al 2005

Para la medición del nivel de productividad en cada obra, se realizó la siguiente clasificación de los tipos de trabajo:

Trabajo Productivo	**TP**
• Actividades Productivas	P
• Habilitación de material	HM
Trabajo Contributorio	**TC**
• Transporte de todo	T
• Limpieza de todo	L
• Dar y recibir instrucciones	I
• Mediciones	M
• Otros	O
Trabajo No Contributorio	**TNC**
• Viajes	V

• Esperas	E
• Tiempo Ocioso	TO
• Trabajo Rehecho	TR
• Otro	OT

Tabla Nº4 : *Clasificación y codificación del trabajo*

El detalle de las actividades consideradas dentro de cada uno de cada tipo de trabajo puede leerse en el acápite 3.1 del presente informe (Página 32).

La siguiente tabla, muestra los porcentajes de tiempos del trabajo, obtenidos en cada una de las obras analizadas, disgregando los Trabajos Productivos (TP), Contributorios (TC) y No Contributorios (TNC).

NIVEL GENERAL DE ACTIVIDAD DE LA OBRA (NGO)

Obra	TP		TC					TNC				
	P	HM	T	L	I	M	O	V	E	TO	TR	OT
1	29.6%	11.0%	15.6%	5.7%	4.1%	6.4%	5.0%	8.5%	7.1%	4.8%	0.0%	2.1%
2	25.1%	14.3%	20.4%	1.4%	5.8%	3.5%	7.9%	7.6%	9.6%	2.9%	0.1%	1.5%
3	29.5%	9.8%	14.4%	2.2%	5.6%	2.9%	10.9%	9.0%	11.8%	1.2%	0.8%	2.2%
4	16.1%	14.5%	15.0%	1.0%	2.8%	4.6%	7.0%	14.7%	**15.5%**	**8.6%**	0.0%	0.1%
5	28.2%	5.3%	16.0%	7.0%	6.2%	7.8%	3.1%	12.2%	7.5%	4.5%	0.7%	1.5%
6	22.6%	16.6%	16.9%	3.6%	5.7%	2.4%	7.4%	10.6%	9.8%	2.4%	0.6%	1.7%
7	18.9%	12.1%	**28.0%**	3.9%	6.1%	4.5%	6.1%	10.1%	6.8%	0.5%	0.7%	2.6%
8	**31.2%**	3.9%	24.3%	4.4%	5.0%	4.6%	7.0%	10.9%	5.5%	2.1%	0.5%	0.9%
9	18.5%	12.5%	22.6%	4.4%	5.9%	7.5%	6.3%	12.3%	4.7%	2.4%	0.3%	2.7%
10	25.4%	4.0%	14.7%	2.8%	4.4%	6.7%	14.0%	12.5%	11.1%	1.5%	0.1%	2.8%
11	20.8%	9.3%	16.4%	5.1%	5.0%	8.0%	13.1%	12.1%	3.4%	6.4%	0.5%	0.2%
12	20.5%	**17.4%**	19.1%	4.2%	5.9%	6.1%	7.2%	10.8%	3.3%	0.6%	0.0%	**5.0%**
13	25.0%	3.1%	18.3%	4.3%	7.2%	3.8%	11.9%	13.3%	10.6%	0.6%	0.1%	1.9%
14	17.5%	12.0%	18.9%	2.7%	5.9%	6.5%	1.3%	15.7%	10.7%	6.9%	1.3%	0.5%
15	22.8%	11.9%	18.6%	6.5%	4.3%	4.0%	10.7%	10.3%	6.8%	1.5%	0.6%	2.2%
16	15.6%	13.2%	14.8%	3.7%	9.3%	**15.6%**	6.8%	13.1%	4.7%	0.7%	0.7%	2.0%
17	15.0%	12.3%	24.6%	3.5%	6.7%	5.3%	8.7%	17.9%	3.5%	0.8%	0.1%	1.6%
18	16.5%	5.9%	24.5%	2.6%	8.0%	6.5%	1.4%	16.8%	7.3%	4.9%	**4.8%**	0.8%
19	26.4%	6.8%	19.2%	5.1%	6.4%	4.3%	0.3%	**18.0%**	8.1%	4.4%	0.6%	0.4%
20	24.2%	3.7%	22.6%	5.1%	5.0%	5.7%	12.1%	13.3%	6.1%	0.4%	0.5%	1.6%
21	20.4%	8.4%	15.3%	1.8%	6.0%	6.2%	**16.1%**	15.1%	7.3%	1.0%	0.0%	2.4%
22	22.2%	6.7%	23.5%	5.4%	5.4%	3.7%	6.0%	15.2%	8.7%	1.3%	0.7%	1.4%
23	22.1%	3.3%	22.1%	6.6%	7.2%	5.4%	9.6%	14.7%	4.4%	1.0%	0.8%	2.8%
24	13.1%	9.5%	18.0%	**9.1%**	6.4%	5.8%	10.8%	16.1%	5.8%	1.4%	1.7%	2.5%
25	29.2%	4.4%	11.7%	2.1%	**9.9%**	8.2%	14.7%	8.5%	8.3%	1.4%	0.0%	1.5%
26	25.6%	4.9%	14.3%	4.9%	7.2%	5.8%	8.4%	15.1%	8.1%	3.5%	1.4%	0.8%

Tabla Nº5 : *Porcentajes obtenidos de cada tipo de trabajo*

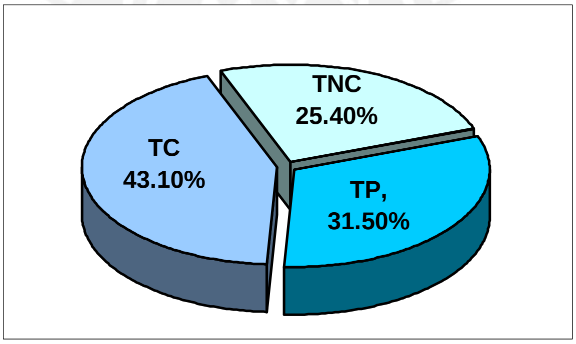
2.1.1. Nivel de Productividad Promedio

En la *Tabla Nº6*, mostramos los porcentajes por actividad, obtenidos a partir del promedio de las 26 obras analizadas.

ACTIVIDAD			PROMEDIO
TP	P	Trabajo Productivo	22.40%
	HM	Habilitación de material	9.10%
TC	T	Transporte de todo	18.80%
	L	Limpieza de todo	4.20%
	I	Dar y recibir instrucciones	6.00%
	M	Mediciones	5.80%
	O	Otros	8.20%
TNC	V	Viajes	12.90%
	E	Esperas	7.60%
	TO	Tiempo ocioso	2.60%
	TR	Trabajo rehecho	0.70%
	OT	Otros	1.70%

Tabla Nº6 : *Porcentajes promedios obtenidos de cada tipo de trabajo, año 2005*

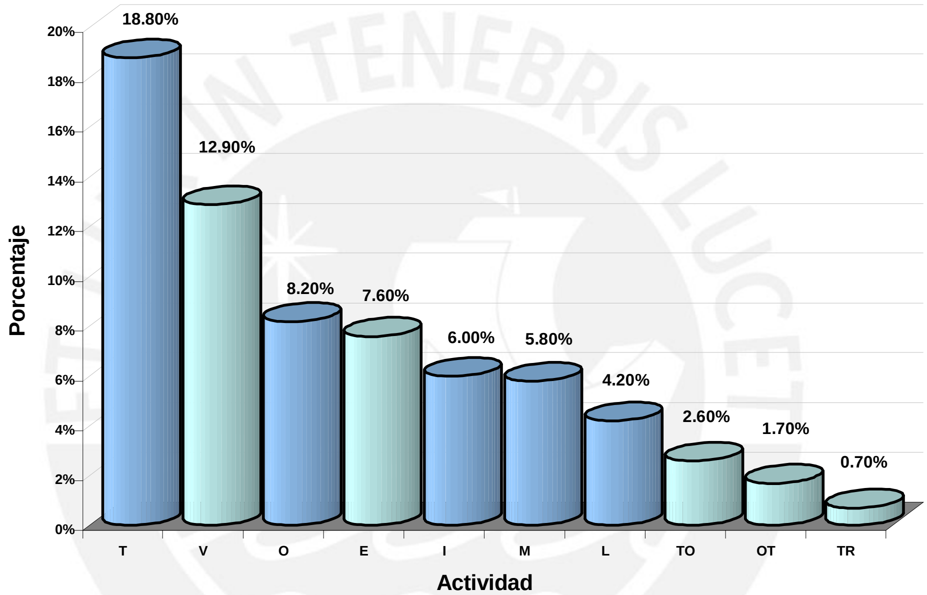
Clasificación del tipo de trabajo en el año 2005



Cuadro Nº7 : *Porcentajes promedios de cada tipo de trabajo*

Según el presente estudio el Nivel Promedio de Productividad de la mano de obra en obras de edificación para vivienda en Lima Metropolitana resulta ser de 31.50%, observándose que la mayor cantidad de tiempo, 43%, es dedicado a actividades contributorias.

En el siguiente diagrama se muestran las actividades no productivas organizadas en orden descendente. Donde podemos notar que las actividades de Transportes (T) y Viajes (V) son las de mayor incidencia con 18.80% y 12.90% respectivamente.

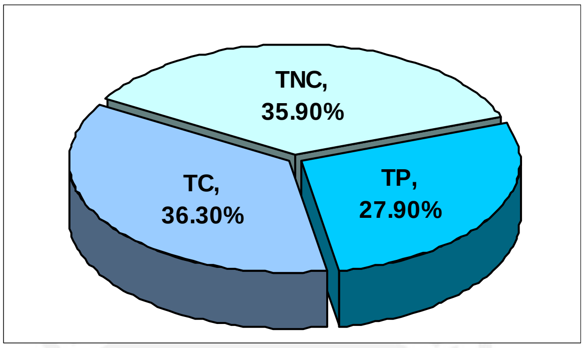


Cuadro Nº8 : *Diagrama de Pareto de las actividades No Productivas*

Vemos que la actividad de Otros contributorios (O), también resulta ser significativa, con 8.20%. En ella se consideraron como, revisiones y actividades de apoyo como; cuando el personal obrero sostiene algún elemento para que otro personal pueda colocarlo, por ejemplo en el caso del acero, cuando atortolan, hay un personal que sostiene la barra para que otro la pueda asegurar; en el caso del encofrado antes de colocar hay una persona sosteniendo los paneles a encofrar, mientras otro revisa que se este colocando bien y en el caso de vaciados de concreto, se observa esta actividad cuando algunos obreros sostienen la manguera para poder vaciar el concreto).

2.1.2. Nivel de Productividad según la investigación realizada en el año 2000

En un estudio realizado el año 2000 con la asesoría del Ing Virgilio Ghio, se encontraron los siguientes resultados:



Cuadro Nº9 : *Distribución de tipo de trabajo – año 2000*

Comparación de resultados con los obtenidos el año 2000

Para poder comparar los resultados actuales con los obtenidos el 2000, es necesario analizar nuestros datos a partir de los mismos parámetros que se consideraron en dicha investigación.

De modo ilustrativo, hemos considerado oportuno mostrar el siguiente cuadro, en el cual mostramos la diferencia de criterios entre ambas mediciones:

ACTIVIDAD EVALUADA	TESIS 2000	TESIS 2005
CONCRETO:		
_ *Vaciado*	PRODUCTIVO	PRODUCTIVO
_ *Vibrado*	PRODUCTIVO	PRODUCTIVO
_ *Chuceado*	PRODUCTIVO	PRODUCTIVO
_ *Lampeado*	PRODUCTIVO	PRODUCTIVO
_ *Dar acabado a la superficie*	PRODUCTIVO	PRODUCTIVO
_ *Preparar mezcla*	**PRODUCTIVO**	**HABILITACION**
_ *Curado*	PRODUCTIVO	PRODUCTIVO
_ *Abastecimento de los componentes*	CONTRIBUTORIO	CONTRIBUTORIO
ENCOFRADO:		
_ *Colocación de paneles*	PRODUCTIVO	PRODUCTIVO
_ *Colocación puntales y otros elementos*	PRODUCTIVO	PRODUCTIVO
_ *Reforzamiento encofrado (grapas, alambre, clavos)*	PRODUCTIVO	PRODUCTIVO
_ *Desencofrado*	PRODUCTIVO	PRODUCTIVO
_ *Fabricar paneles*	**PRODUCTIVO**	**HABILITACION**
_ *Cortar madera para paneles*	**CONTRIBUTORIO**	**HABILITACION**
_ *Limpieza de paneles*	CONTRIBUTORIO	CONTRIBUTORIO
_ *Sostener encofrado*	CONTRIBUTORIO	CONTRIBUTORIO
_ *Armado de andamios*	CONTRIBUTORIO	CONTRIBUTORIO

ACERO:		
_ *Colocación y acomodo de barras de acero*	PRODUCTIVO	PRODUCTIVO
_ *Atortolado*	PRODUCTIVO	PRODUCTIVO
_ *Armando de elementos estructurales fuera de sitio*	PRODUCTIVO	PRODUCTIVO
_ *Habilitación de acero (cortado y doblado)*	**PRODUCTIVO**	**HABILITACION**
_ *Sostener barra*	CONTRIBUTORIO	CONTRIBUTORIO
_ *Marcar con tiza las barras y encofrado*	CONTRIBUTORIO	CONTRIBUTORIO
_ *Armado de andamios*	CONTRIBUTORIO	CONTRIBUTORIO
ALBAÑILERIA:		
_ *Colocación de mortero en junta vertical y horizontal*	PRODUCTIVO	PRODUCTIVO
_ *Colocación de ladrillos y mechas de acero*	PRODUCTIVO	PRODUCTIVO
_ *Preparación de mortero*	**PRODUCTIVO**	**HABILITACION**
_ *Preparación de mezcla seca*	**CONTRIBUTORIO**	**HABILITACION**
_ *Cortar y humedecer ladrillo*	**CONTRIBUTORIO**	**HABILITACION**
_ *Abastecimiento de mezcla a otro recipiente*	CONTRIBUTORIO	CONTRIBUTORIO
_ *Armado de andamios*	CONTRIBUTORIO	CONTRIBUTORIO
_ *Limpieza de mortero*	CONTRIBUTORIO	CONTRIBUTORIO
TARRAJEO		
_ *Pañeteado*	PRODUCTIVO	PRODUCTIVO
_ *Paleteado*	PRODUCTIVO	PRODUCTIVO
_ *Regleado de superficie*	PRODUCTIVO	PRODUCTIVO
_ *Preparación de mortero*	**PRODUCTIVO**	**HABILITACION**
_ *Preparación de mezcla seca*	**PRODUCTIVO**	**HABILITACION**
_ *Abastecimiento de mezcla a otro recipiente*	CONTRIBUTORIO	CONTRIBUTORIO
_ *Armado de andamios*	CONTRIBUTORIO	CONTRIBUTORIO
_ *Limpieza de mortero*	CONTRIBUTORIO	CONTRIBUTORIO
_ *Humeder la pared*	CONTRIBUTORIO	CONTRIBUTORIO
_ *Colocar puntos de referencia*	CONTRIBUTORIO	CONTRIBUTORIO

Tabla Nº6A : *Comparativo de criterios entre tesis del 2005 y el 2000*

La diferencia básica radica en que las actividades evaluadas como Habilitación en el 2005 son consideradas productivas en su totalidad; mientras que, en la tesis del 2000, algunas habilitaciones son consideradas contributorias y otras productivas, tal y como se muestra en el cuadro.

En el resto de actividades contributorias, como los transportes, limpieza, instrucciones y mediciones, no hubo diferencias.

De la misma forma, en las actividades no contributorias, tales como viajes, tiempo ocioso, esperas, trabajo rehecho, descansos, necesidades fisiológicas y otros, no se encontró diferencia de criterios.

Ya que medimos con suficiente detalle lo referente a las habilitaciones, pudimos disgregarlas y adecuarlas al criterio utilizado en el año 2000;

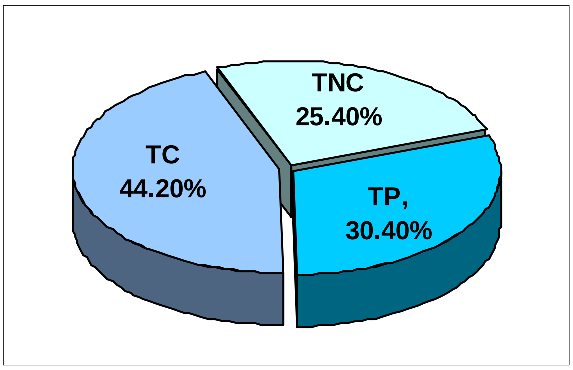
obteniendo el siguiente cuadro, el cual representa la productividad del año 2005 con el criterio tomado el año 2000:

ACTIVIDAD			PROMEDIO
TP	P	Trabajo Productivo	22.40%
TP	HM	Habilitación de material	8.00%
TC	PM	Preparación de material	4.00%
TC	T	Transporte de todo	18.80%
TC	L	Limpieza de todo	4.20%
TC	I	Dar y recibir instrucciones	6.00%
TC	M	Mediciones	5.80%
TC	O	Otros	5.30%
TNC	V	Viajes	12.90%
TNC	E	Esperas	7.60%
TNC	TO	Tiempo ocioso	2.60%
TNC	TR	Trabajo rehecho	0.70%
TNC	OT	Otros	1.70%

Tabla Nº7 : *Clasificación actual del tipo de trabajo a partir de la investigación del 2000*

Se agregó una actividad, que se consideró en ese análisis dentro de otros contributorios, la actividad de Preparación de Material (PM), que incluye humedecer ladrillos, partir ladrillos, cortar madera, etc. Si se observa con detenimiento la Tabla 6A, veremos que Preparación de Material corresponde a las actividades de habilitación del año 2005 que fueron consideradas contributorias en el año 2000.

En el siguiente gráfico podemos ver el promedio resultado de las mediciones considerando los mismos parámetros tomados el año 2000.



Cuadro Nº10 : *Clasificación actual del tipo de trabajo a partir de la investigación del 2000*

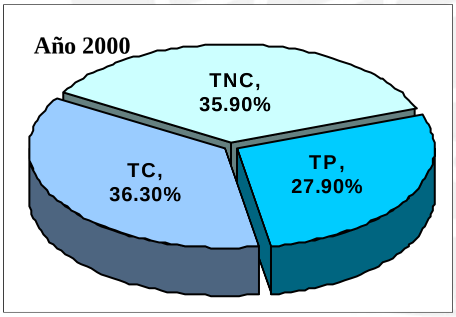
Vemos que la diferencia entre las mediciones realizadas considerando los parámetros planteados en esta investigación y lo definido en la investigación del año 2000 es de 1.10%. Diferencia que no resulta ser muy significativo, debido a que tener un nivel de productividad de 30.40% o 31.50%, implicaría que de las 8 horas laborales los trabajadores sólo realizan 2.5 horas trabajos productivos.

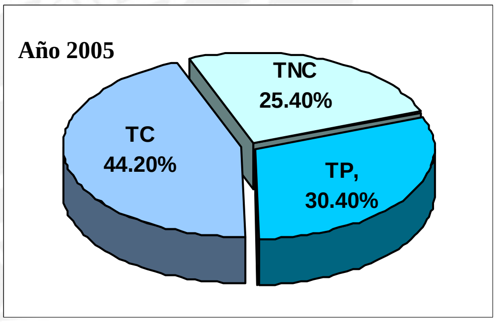
A partir de los resultados obtenidos con los parámetros considerados en la investigación del 2000, podemos afirmar que la productividad en Lima Metropolitana incrementó en 2.40%, que no es muy considerable, tomando en cuenta que el error máximo de la medición es de 1.90%.

Comparando los resultados, el hallado hace cinco años y los resultados obtenidos en este estudio, obtenemos el siguiente cuadro:

ACTIVIDAD			MEDICIONES 2000	MEDICIONES 2005
TP	P	Trabajo Productivo	28.00%	30.40%
TC	T	Transporte de todo	14.00%	18.80%
	L	Limpieza de todo	4.00%	4.20%
	I	Dar y recibir instrucciones	3.00%	6.00%
	M	Mediciones	5.00%	5.80%
	O	Otros	11.00%	9.30%
TNC	V	Viajes	13.00%	12.90%
	E	Esperas	6.00%	7.60%
	TO	Tiempo ocioso	10.00%	2.60%
	TR	Trabajo rehecho	3.00%	0.70%
	OT	Otros	3.00%	1.70%

Tabla Nº8: *Comparación entre las mediciones – Año 2000 y 2005*





Cuadro Nº11: *Comparación entre las mediciones – Año 2000 y 2005*

En la que podemos notar que las actividades no contributorias han disminuido, pero eso no ocurre con las contributorias. Donde podemos apreciar que la actividad de instrucciones ha duplicado su porcentaje. Algo similar ocurre con la actividad de transportes conde su porcentaje incremento.

2.2. Relación Productividad con el tipo de estructura

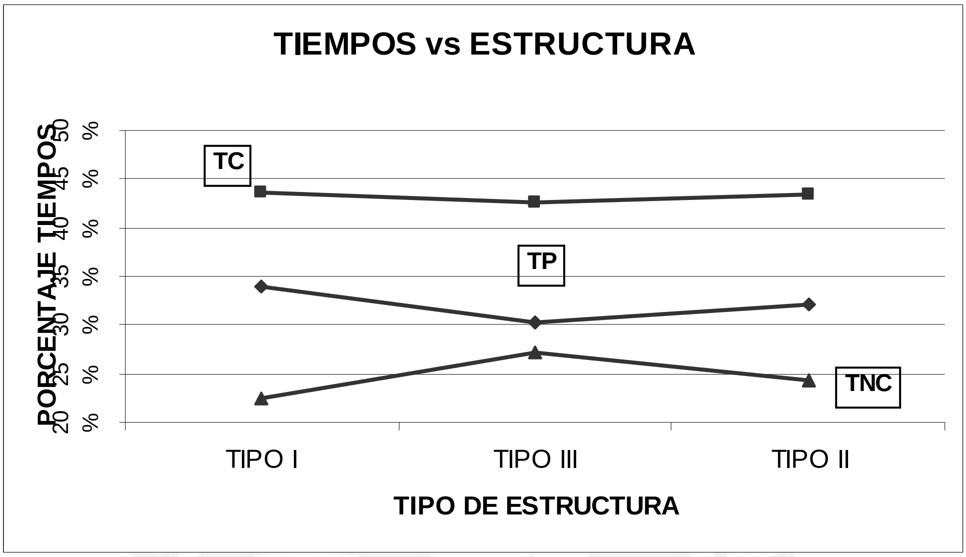
Utilizando los criterios indicados en páginas anteriores, cada uno de los 26 proyectos fueron clasificados dentro de tres tipos de estructuras vinculados a procesos constructivos similares.

Una vez agrupados, se calculó la productividad promedio por cada tipo, arrojando los resultados que mostramos en el siguiente cuadro:

RESULTADOS DE MEDICIONES				TIPO DE ESTRUCTURA	RESULTADOS PROMEDIO		
COD	TP	TC	TNC		TP	TC	TNC
1	40.64%	36.77%	22.59%	TIPO I	**33.92%**	43.62%	22.46%
9	31.02%	46.66%	22.32%				
11	30.11%	47.44%	22.45%				
4	30.60%	30.38%	39.01%	TIPO II	**30.26%**	42.58%	27.15%
3	39.27%	35.87%	24.86%				
6	39.15%	35.95%	24.90%				
7	30.96%	48.59%	20.45%				
14	29.57%	35.26%	35.17%				
15	34.75%	43.95%	21.30%				
16	28.78%	50.07%	21.15%				
17	27.32%	48.83%	23.85%				
18	22.44%	42.85%	34.71%				
21	28.84%	45.41%	25.75%				
22	28.93%	43.80%	27.28%				
24	22.58%	50.02%	27.40%				
2	39.46%	38.98%		TIPO III	**32.20%**	43.51%	24.29%
5	33.55%	40.04%	26.41%				
8	35.07%	45.19%	19.75%				
10	29.45%	42.58%	27.96%				
12	37.89%	42.51%	19.60%				
20	27.88%	50.32%	21.80%				
23	25.41%	51.00%	23.59%				
26	30.49%	40.72%	28.79%				
25	33.64%	46.64%	19.72%				

Tabla Nº9: *Comparación entre tipo de estructura y productividad*

A manera ilustrativa preparamos el siguiente gráfico:



Cuadro Nº12 *Comparación entre tipo de estructura y productividad*

Observamos que no hay una tendencia lineal en cuanto a la relación entre el tipo de estructura y los tiempos productivos, es decir, que si consideramos el error del 1.90% de nuestras mediciones, los rangos entre los TP, TC y TNC de los tres tipos se interceptarán.

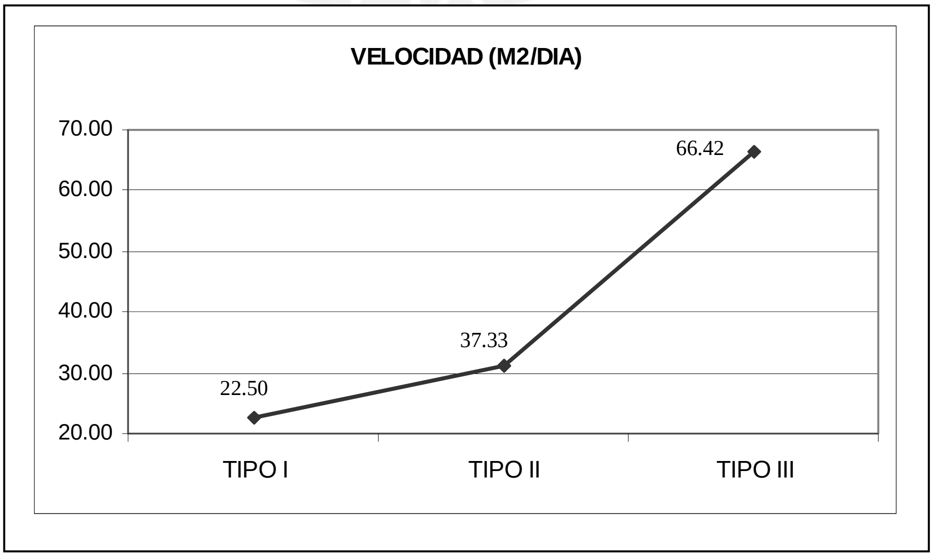
Sin embargo, introducimos un nuevo indicador, el cual es la velocidad de avance del casco estructural. Se obtuvo a partir de la secuencia constructiva de los proyectos, considerando el cociente entre el área de losa vaciada y los días que se demoran en armarlas. Cabe resaltar que esto incluye el levantamiento de los elementos verticales que sostienen la losa.

Relacionamos la velocidad de avance del caso estructural y los tipos de estructura y obtuvimos los siguientes resultados:

PARAMETROS DE VELOCIDAD				TIPO DE ESTRUCTURA	VELOCIDAD PROMEDIO (M2/DIA)
COD	AREA (M2)	TIEMPO (DIA)	VELOCIDAD (M2/DIA)		
1	135	6	22.50		
9	200	12	16.67	TIPO I	22.50
11	340	12	28.33		
4	83	2	41.50		
14	500	12	41.67		
16	250	12	20.83		
17	500	12	41.67		
21	600	15	40.00		
22	400	7	57.14	TIPO II	37.33
7	176	6	29.33		
15	600	18	33.33		
18	680	18	37.78		
24	240	8	30.00		
2	113	2	56.25		
5	96	2	48.08		
8	175	2	87.50		
10	143	2	71.25		
12	320	12	26.67	TIPO III	**66.42**
20	65	1	65.00		
23	485	6	80.83		
26	127	1	127.00		
25	80	1	80.00		

Tabla Nº10 *Comparación entre tipo de estructura y velocidad*

A manera ilustrativa preparamos el siguiente gráfico:



Cuadro Nº13 *Comparación entre tipo de estructura y productividad*

Aquí observamos claramente que los sistemas estructurales de muros delgados alcanzan velocidades mucho mayores que los otros sistemas, sin necesidad de ser más productivos.

Le quisimos dar una interpretación práctica a los valores de velocidad hallados y para ello tomamos como ejemplo un departamento de 80 m^2, el cual es un área promedio en la actualidad, y apuntamos que si fuera diseñado con albañilería demoraría 3.60 días es construirse; si fuera diseñado con pórticos de columnas y/o placas, 2.60 días; y si fuera un sistema de muros de espesor delgados, 1.20 días. Por supuesto, gran parte de la velocidad es definida por el tipo de programación empleada, por lo que los valores indicados son referenciales.

2.3. Grado de integración entre subcontratistas y contratistas

2.3.1. Clasificación de los niveles de integración

Como se explicó anteriormente, en base a los criterios utilizados para definir el grado de integración entre los participantes de un proyecto, las obras analizadas fueron clasificadas en tres tipos en base a un sistema de puntuación establecido por nosotros. La información utilizada para dicha clasificación fue obtenida mediante la encuesta al personal técnico y administrativo.

En el siguiente cuadro se aprecian las características de cada tipo propuesto, en donde las obras Tipo I presentan el mayor nivel de integración:

CUADRO DE CLASIFICACIÓN DE NIVELES DE INTEGRACIÓN

	TIPO I	TIPO II	TIPO III
1. TIPO DE CONTROL	Control Alto Cuando los controles son diarios o muy frecuentes y, además del avance y calidad constructiva, evalúan temas como costos, productividad, entre otros.	Control Mediano Cuando se realizan controles de avance y calidad constructiva de manera continua durante la ejecución del proyecto.	Control bajo o no controlado Cuando no se ejerce ningún control o sólo se centra en el avance del subcontratista. Éste se realiza cada cierto tiempo de forma esporádica.
2. TIPO DE CONTRATO	Óptimo Es el contrato que, además de lo especificado para el escrito, incluye especificaciones de la actividad subcontratada (según el riesgo que aporte el subcontratista). Además, puede incluir un sistema de premios y/o sanciones.	Formal Es el contrato que tiene un documento escrito, en el cual se indica solamente el metrado a realizar, el plazo a cumplir y el monto de pago fijado. Debido a la poca claridad con que se detalla la tarea a realizar, su interpretación suele ser de forma subjetiva y fácil de malinterpretar.	Informal Es el contrato en el cual no hay un documento que lo sustente. De modo que es susceptible de modificaciones en cualquier momento y sin respeto a ambas partes. No se puede ejercer ningún tipo de acción legal y puede darse el caso de abusos por parte del contratista.
3. CONTINUIDAD	Alta En el caso de que el contratista y subcontratista tienen varios proyectos trabajando en conjunto.	Inicial En el caso del segundo o tercer proyecto que realiza la empresa con el mismo subcontratista. Es decir, si es que existe una posibilidad de continuidad alta.	Nula Si es que la empresa contratista cambia de subcontratista para cada proyecto.
4. MODO DE ELECCIÓN	Sistema de Evaluación La elección se realiza a través de un sistema de evaluación, el cual engloba criterios como precio, calidad, trabajos anteriores, etc. además que se analiza el efecto costo – beneficio.	(*) Las obras Tipo II cumplen con lo especificado para las obras Tipo I, en al menos 2 de las 3 características mencionadas en los puntos (4), (5) y (6).	Menor Costo Se refiere a la elección del subcontratista teniendo como única consideración que la propuesta ganadora sea la más barata de todas.
5. COSTO	Bilateral Cuando ambas partes salen beneficiadas al término del contrato, habiendo cumplido o superado sus espectativas.	(*)	Unilateral Cuando sólo se beneficia una de las partes, mayormente el contratista, pudiendo provocar disminución en el márgen de ganancia, pérdidas o cero utilidad a la otra parte involucrada.
6. PARTICIPACIÓN EN LA PLANIFICACIÓN	Activa Si es que el subcontratista participa en algún tipo de planificación a largo, mediano y corto plazo.	(*)	Pasiva Si es que el subcontratista no participa en la planificación. También está incluida en esta categoría el caso en el que el subcontratista se entera del sector de avance al iniciar la jornada laboral.

Tabla Nº11: *Cuadro de clasificación del tipo de los niveles de integración*

De las 26 obras analizadas, 23 de ellas presentaban algún tipo de subcontrato. Esto quiere decir que alrededor del 88% de las obras en Lima Metropolitana deciden subcontratar algunas actividades, lo cual es comparable con la tendencia que actualmente ocurre en muchos lugares del mundo.

Para poder clasificar las empresas en los tipos descritos anteriormente, se decidió asignarle puntaje a cada uno de los criterios de evaluación, según se indica en el siguiente cuadro:

CUADRO DE PUNTAJES ASIGNADOS

1. Tipo de control	ALTO	MEDIANO	BAJO O NINGUNO
	100	67	33
2. Tipo de contrato	OPTIMO	FORMAL	INFORMAL
	100	67	33
3. Continuidad	ALTA	INICIAL	NULA
	100	75	50
4. Modo de elección	SISTEMA DE EVALUACION	MENOR COSTO	
	100	50	
5. Costo	UNILATERAL	MENOR COSTO	
	100	50	
6. Participación en la planificación	ACTIVA	PASIVA	
	100	50	

Tabla Nº11A: *Cuadro de puntajes asignados a cada criterio de evaluación*

Ya que les asignamos puntaje a cada uno de los criterios de evaluación, es imperativo definir límites sobre los cuales discernir cada empresa en los tres tipos descritos en la Tabla Nº11.

De este modo se planteó la siguiente puntuación:

PUNTAJES LIMITES PARA LA CLASIFICACION

	MINIMOS PUNTAJES PARA		
	TIPO III	**TIPO II**	**TIPO I**
1. Tipo de control	BAJO 33	MEDIANO 67	ALTO 100
2. Tipo de contrato	INFORMAL 33	FORMAL 67	OPTIMO 67
3. Continuidad	NULA 50	INICIAL 75	ALTA 75
4. Modo de elección	MENOR COSTO 50	SIST. EVAL. (*) 100	SIST. EVAL. 100
5. Costo	UNILATERAL 50	BILATERAL (*) 100	BILATERAL 100
6. Participación	PASIVA 50	PASIVA (*) 50	ACTIVA 100
LÌMITES MÌNIMOS	266	459	542

(*) Está cumpliendo con dos de las tres caracteríscas esenciales para el tipo máximo en los puntos 4, 5 o 6. Independiente de la característica que se incumpla, se obtiene el mismo puntaje.

Tabla Nº11B: *Cuadro de puntajes límites para la clasificación*

De esta forma se obtiene que para que una empresa sea considerada dentro del Tipo II, su puntuación debe estar entre 459 y 541 puntos. Puntuaciones superiores indicaran que la empresa se encuentra dentro del Tipo I y de la misma forma, puntuaciones menores indicaran que la empresa se encuentra dentro del Tipo III.

Para mayor información, consultar el Anexo Nº04 en donde se muestra el cuadro con el que se clasificaron las obras.

2.4. Relación entre el Nivel de Integración y la productividad

El objetivo de esta parte del trabajo es mostrar los resultados obtenidos respecto a los subcontratos en la construcción y compararlos con los datos de productividad arrojados por las mediciones a fin de averiguar si es que existe alguna relación entre ambos factores.

A continuación se presentan los resultados obtenidos en base a la clasificación indicada y además se están colocando los resultados de productividad de las obras:

NIVEL DE INTEGRACIÓN

MEDICIONES - NIVEL GENERAL DE OBRA							
NUM	**TP**	**TC**	**TNC**	**CLASIFICACIÓN**	**TP PROMEDIO**	**TC PROMEDIO**	**TNC PROMEDIO**
1	40.64%	36.77%	22.59%	TIPO I	**40.64%**	**36.77%**	**22.59%**
7	30.96%	48.59%	20.45%	TIPO II	**32.98%**	**45.02%**	**22.00%**
8	35.07%	45.19%	19.75%	TIPO II			
15	34.75%	43.95%	21.30%	TIPO II			
25	33.64%	46.64%	19.72%	TIPO II			
26	30.49%	40.72%	28.79%	TIPO II			
9	31.02%	46.66%	22.32%	TIPO III	**30.56%**	**42.46%**	**26.98%**
2	39.46%	38.98%	21.56%	TIPO III			
3	39.27%	35.87%	24.86%	TIPO III			
4	30.60%	30.38%	39.01%	TIPO III			
5	33.55%	40.04%	26.41%	TIPO III			
6	39.15%	35.95%	24.90%	TIPO III			
10	29.45%	42.58%	27.96%	TIPO III			
11	30.11%	47.44%	22.45%	TIPO III			
13	28.15%	45.43%	26.42%	TIPO III			
14	29.57%	35.26%	35.17%	TIPO III			
16	28.78%	50.07%	21.15%	TIPO III			
18	22.44%	42.85%	34.71%	TIPO III			
19	33.18%	35.23%	31.59%	TIPO III			
20	27.88%	50.32%	21.80%	TIPO III			
22	28.93%	43.80%	27.28%	TIPO III			
23	25.41%	51.00%	23.59%	TIPO III			
24	22.58%	50.02%	27.40%	TIPO III			

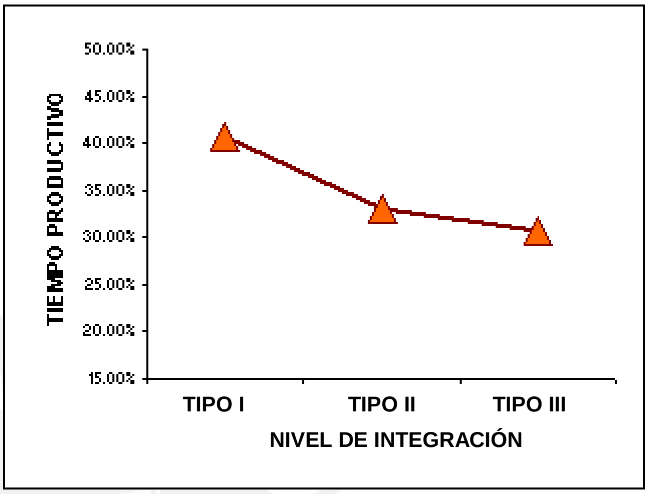
Tabla Nº12: *Comparación entre la productividad y el nivel de integración*

Para poder apreciar mejor los resultados, se presenta el siguiente gráfico:

TIPO I:
Integración estratégica

TIPO II:
Integración en vías de desarrollo

TIPO III:
No hay Integración



Cuadro Nº14: *Comparación entre la productividad y el nivel de integración*

Como se puede apreciar en el gráfico, a mayor grado de integración se obtiene un mayor tiempo productivo. Esto se debe a que las obras TIPO I manejan una mejor forma de gestión y administración de subcontratos en comparación con los otros tipos de obras. Si bien la diferencia es bastante clara entre las obras TIPO I y TIPO II (7.66% de diferencia), la diferencia entre las obras TIPO II y TIPO III es nada relevante (2.30% de diferencia) considerando que estas mediciones tienen un error de 1.90%.

Con la finalidad de entender mejor cuales han sido los resultados de la clasificación de las diferentes obras según los seis criterios de clasificación expuestos, se presenta el siguiente cuadro:

CUADRO DE CLASIFICACIÓN DE NIVELES DE INTEGRACIÓN

	TIPO I	TIPO II	TIPO III
1. TIPO DE CONTROL	Control Alto 26.09%	Control Mediano **47.83%**	Control bajo o no controlado 26.09%
2. TIPO DE CONTRATO	Óptimo 30.43%	Formal **65.22%**	Informal 4.35%
3. CONTINUIDAD	Alta **52.17%**	Inicial 21.74%	Nula 26.09%
4. MODO DE ELECCIÓN	Sistema de Evaluación 39.13%	(*) TIPO I 80% del total de TIPO II TIPO III 20% del total de TIPO II	Menor Costo **60.87%**
5. COSTO	Bilateral 13.04%	(**) TIPO I 40% del total de TIPO II TIPO III 60% del total de TIPO II	Unilateral **86.96%**
6. PARTICIPACIÓN EN LA PLANIFICACIÓN	Activa 17.39%	(***) TIPO I 60% del total de TIPO II TIPO III 40% del total de TIPO II	Pasiva **82.61%**

Tabla Nº13: *Productividad según criterio de clasificación*

(*) Del total de obras clasificadas como Tipo II, el 80% utiliza como modo de elección el Sistema de Evaluación y el 20% restante el de Menor Costo.

(**) Del total de obras clasificadas como Tipo II, el 40% propicia un beneficio bilateral mientras que el 60% restante busca un beneficio unilateral.

(***) Del total de obras clasificadas como Tipo II, el 60% fomenta una participación activa del subcontratista en la clasificación mientras que el 40% restante lo hace de forma pasiva.

Los porcentajes que se indican, salvo en los casilleros marcados con (*) en la Tabla No 11, representan el porcentaje de obras cuyas características coincide con lo indicado por la matriz. De esta forma se aprecia que la mayoría de empresas realiza un control mediano, con contratos de tipo formal según nuestra descripción (Ver Parámetros de clasificación punto IV-1-1.1. página 36) y mantienen una alta continuidad con sus subcontratistas.

Lo que podría explicar el porqué de la similitud en los resultados de productividad entre las empresas del TIPO II y del TIPO III es el hecho de que la mayoría de empresas optan por utilizar como modo de elección la propuesta con menor costo, con beneficio sólo para el contratista (esto es el denominado principio de suma cero, el cual indica que mientras una empresa se ve beneficiada la otra pierde o deja de ganar) y en donde el subcontratista, en la gran mayoría de los casos (aproximadamente en el 80% de ellos), se ve alejado de la toma de decisiones y de la participación en la planificación.

En el proceso de toma de datos, también se consultó a los subcontratistas cual o cuales eran los insumos que ellos aportaban a la obra, siendo las opciones Mano de Obra (MO), Materiales (MAT), Diseño (DIS) y Mantenimiento (MANT). Según los datos recopilados, obtenemos el siguiente cuadro:

Aporte del Subcontratista

MO	75	**79%**
MO MAT	17	**18%**
MO MAT DIS	2	**2%**
MO MAT DIS MANT	1	**1%**
Total Act. Subcontratada	95	

Tabla Nº13A: Porcentajes de actividades subcontratadas.

Como se muestra en la tabla No 13A, de todas las actividades subcontratadas consideradas, aproximadamente el 80% de ellas involucra subcontratas de sólo mano de obra (MO). Esto explica también el motivo por el cual se producen los resultados mostrados en el cuadro superior en los puntos (4), (5) y (6). Dada la gran cantidad de subcontratistas de este tipo, la selección suele ser de gran competencia lo que motiva que los precios se bajen involucrando muchas veces bajas en calidad. Esto también afecta al subcontratista ya que al reducir sus costos por conseguir el trabajo, tiene que sacrificar o su ganancia o la calidad de su trabajo (por ejemplo contratando peones para un trabajo que requiere operarios, o personal no especializado que se dedica a realizar actividades múltiples: se puede ver fierreros que se encuentran también encofrando o haciendo trabajos de albañilería). Además, este tipo de subcontrata en la mayoría de los casos se encuentra totalmente subordinado a lo ordenado por el residente o el ingeniero responsable, quedando relegado totalmente de la toma de decisiones.

Por último, se muestra un cuadro en donde se muestra el porcentaje de obras que pertenecen a un tipo determinado:

NIVEL DE INTEGRACIÓN

NUM	CLASIFICACIÓN	%
1	TIPO I	**4.35%**
7	TIPO II	**21.74%**
8	TIPO II	
15	TIPO II	
25	TIPO II	
26	TIPO II	
2	TIPO III	**73.91%**
3	TIPO III	
4	TIPO III	
5	TIPO III	
6	TIPO III	
9	TIPO III	
10	TIPO III	
11	TIPO III	
13	TIPO III	
14	TIPO III	
16	TIPO III	
18	TIPO III	
19	TIPO III	
20	TIPO III	
22	TIPO III	
23	TIPO III	
24	TIPO III	

TOTAL: 23 OBRAS
(Las otras 3 obras de las 26 analizadas no tenìan subcontratos).

Tabla Nº13B: Porcentajes de obras por cada tipo.

2.5. Relación entre la productividad y el porcentaje de obra subcontratada

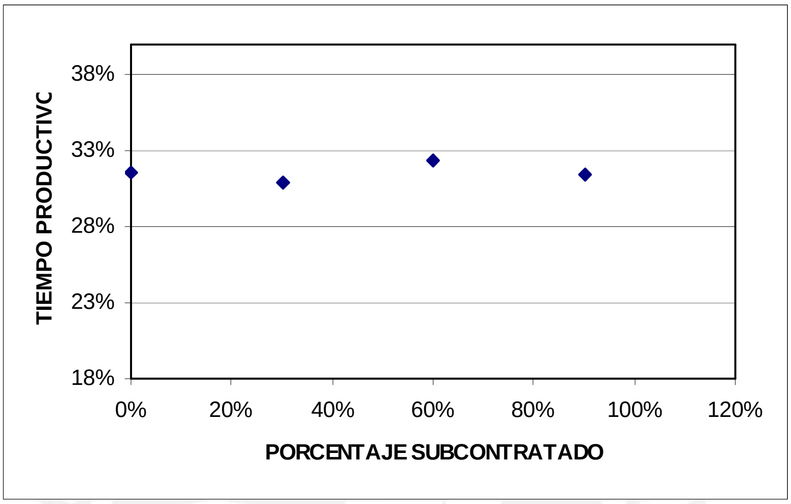
En el siguiente cuadro se compara la productividad con el porcentaje del presupuesto que se encontraba subcontratado:

MEDICIONES - NIVEL GENERAL DE OBRA				% PRESUPUESTO SUBCONTRATADO			
NUM	TP	TC	TNC	%	TP PROMEDIO	TC PROMEDIO	TNC PROMEDIO
1	40.64%	36.77%	22.59%	22%	32%	44%	24%
11	30.11%	47.44%	22.45%	15%			
12	37.89%	42.51%	19.60%	0%			
15	34.75%	43.95%	21.30%	7%			
17	27.32%	48.83%	23.85%	0%			
19	33.18%	35.23%	31.59%	23%			
20	27.88%	50.32%	21.80%	8%			
21	28.84%	45.41%	25.75%	0%			
24	22.58%	50.02%	27.40%	20%			
25	33.64%	46.64%	19.72%	20%			
26	30.49%	40.72%	28.79%	15%			
7	30.96%	48.59%	20.45%	50%	31%	46%	23%
8	35.07%	45.19%	19.75%	30%			
9	31.02%	46.66%	22.32%	40%			
10	29.45%	42.58%	27.96%	35%			
13	28.15%	45.43%	26.42%	30%			
3	39.27%	35.87%	24.86%	60%	32%	43%	24%
16	28.78%	50.07%	21.15%	60%			
22	28.93%	43.80%	27.28%	65%			
2	39.46%	38.98%	21.56%	100%	31%	39%	29%
4	30.60%	30.38%	39.01%	100%			
5	33.55%	40.04%	26.41%	90%			
6	39.15%	35.95%	24.90%	100%			
14	29.57%	35.26%	35.17%	100%			
18	22.44%	42.85%	34.71%	95%			
23	25.41%	51.00%	23.59%	100%			

Máximo	40.64%	51.00%	39.01%
Mínimo	22.44%	30.38%	19.60%
VALOR PROMEDIO	**31.50%**	**43.10%**	**25.40%**

En el cuadro se han separado las 26 obras en 4 grupos de acuerdo a la cantidad subcontratada respecto del presupuesto (de 0% a 25%, de 25% a 50%, de 50% a 75% y de 75% a 100%).

En el gráfico que se muestra a continuación se aprecia la relación entre los tiempos productivos y el porcentaje del presupuesto subcontratado:



Cuadro Nº15: *Productividad según porcentaje de presupuesto subcontratado*

No se aprecia mayor diferencia entre los valores de tiempos productivos; el promedio máximo es 32% el mínimo es 31% y el promedio es de 31.5%. Este resultado no coincide con lo que mencionan Shimizu y Cardoso, quienes aseguran que el uso adecuado de subcontratos tiende a aumentar la productividad de la mano de obra debido a los efectos de replicación, continuidad y aprendizaje.

Es probable que este resultado se deba a la subcontrata de mano de obra y al problema que acarrea el hecho de subcontratar teniendo como el parámetro más importante de selección el costo.

v. IDENTIFICACION Y DESCRIPCION DE LAS PERDIDAS ENCONTRADAS

En esta etapa de la investigación haremos un listado de una serie de actividades y prácticas comunes en la construcción que en realidad generan pérdidas y que deberían ser corregidas a futuro.

Cada una de ellas ha sido dividida por rubros:

1. Respecto a la Productividad

Para identificar los problemas más frecuentes desde la perspectiva del Ingeniero Residente, se incluyó en el Formato de Identificación de Obra una serie de problemas, los cuales debían ser calificados por los ingenieros como las causas más comunes de pérdida.

De acuerdo a los datos medidos tenemos:

PROBLEMAS FRECUENTES	PORCENTAJE DE INCIDENCIA
Sindicatos, los cuales paralizan las actividades por marchas o por coacción al Ingeniero Residente.	21%
Abastecimiento, en materiales clave como ladrillos, arena, cemento, concreto premezclado, etc.	18%
Subcontratos, los detalles de los problemas se encontrarán más adelante.	17%
Rendimientos, ya que a veces no se presupuesta con el rendimiento adecuado o no se controla adecuadamente el avance de las cuadrillas.	14%
Descoordinaciones, cambios repentinos, falta de compatibilización en el diseño, falta de comunicación entre personal técnico – obrero.	12%
Otros, como problemas financieros, obligaciones municipales en horarios, etc.	9%
Maquinaria, mantenimiento inadecuado o deficiente.	6%
Tramites públicos	3%

Tabla Nº15: *Incidencia de los problemas en subcontratos*

Durante las visitas a las distintas obras se notó un interés de los profesionales por el tema de la productividad, sin embargo no tienen personal dedicado a ello y por los tanto no disminuyen (o eliminan) las pérdidas tales como:

- Exceso de movimientos del personal obrero, es decir, cuando aplica más movimientos físicos en una actividad debido a malas prácticas constructivas o herramientas ineficientes.
- Exceso de transportes, cuando se colocan los materiales “donde haya espacio”, en lugar de hacer un estudio del layout de la obra y del lugar óptimo donde se debe colocar los materiales y equipos para que los recorridos del personal sea mínimos.
- Exceso de inventarios y logística deficiente, cuando se podría optimizar la llegada de los materiales necesarios en el momento adecuado mediante la aplicación del just in time[i].
- Presencia de esperas innecesarias, debido a descoordinaciones o a fallas en un eslabón de la cadena de proveedores, lo cual compromete a los siguientes.
- Poca supervisión o poco seguimiento de las actividades, lo cual hace que la subsanación de errores no sea en el momento adecuado y se generen trabajos rehechos, es decir, eliminar el trabajo hecho hasta antes del error y luego hacerlo de la manera correcta.

Esto último está enfocado a la obra en general, sin embargo, como la presente investigación se ha centrado en el insumo mano de obra, es lógico que indiquemos los problemas comunes que la aquejan y que son las siguientes:

- El personal obrero es rotativo y a menos que se trate de obras de larga duración, no se logra desarrollar habilidades de trabajo de equipo.

[i] Just in time: Método productivo que tiene por objetivos la eliminación del despilfarro, desarrollar un flujo de trabajo simple y una gestión también simple.

- Aplicación de métodos tradicionales de construcción. Debido a que la capacitación no es una práctica usual, la mano de obra siempre emplea los mismos métodos, los cuales son los mismos que les enseñan a las generaciones siguientes.

- El sistema de gestión en la construcción es, por lo general, una política de control, con una tendencia jerárquica vertical. El obrero sólo cumple órdenes y no participa en las decisiones. Esto sumado a que no existe un sistema de incentivos usual, genera un sentimiento de poca motivación y poca identificación con los intereses de la empresa.

2. Respecto al Tipo de estructura

En esta sección indicaremos los problemas encontrados en la etapa anterior a la construcción del proyecto, ya que los problemas durante la ejecución del mismo serán tocados en los otros acápites.

Se encontraron las siguientes observaciones:

- Falta de diálogo entre el ingeniero estructural y el ingeniero encargado de la construcción: No se aplican los principios de constructabilidad.

- Olvidos o detalles omitidos en las estructuras del proyecto, siendo la rectificación de los mismos, motivo para solicitarlo como un adicional al proyecto inicial.

- Muchas de las estructuras de placas delgadas de concreto analizadas no facilitaban el proceso constructivo debido a la gran cantidad de detalles, cortes y complejidades que poseían. Por decir algo, en lugar de poseer vigas chatas en los bordes de las losas que facilitaran la colocación de frisos, se presentaban vigas peraltadas que lo único que hacían era prolongar el proceso de colocación de encofrado, incrementar el trabajo contributorio y disminuir la productividad evaluada. Si bien es cierto esta modificación no se puede realizar en obra sin que incurra en alguna demora, es posible hacerla en planos.

- También se notó en muchas de las obras que no presentaban plantas de la estructura simétrica, lo cual hubiera facilitado mucho el proceso constructivo y el incremento de la curva de aprendizaje de la mano de obra.

3. Respecto al Nivel de Integración de los subcontratos

En general, tras realizar la presente investigación se pudo apreciar que hay un deficiente manejo de las relaciones con los subcontratistas, en donde se pudo corroborar, como ya se hacia presagiar, que el principal criterio de discernimiento entre una opción y otra es el precio directo de la actividad subcontratada.
Esto quiere decir que en la mayoría de los casos la propuesta más económica es la que suele ganar el negocio.

Entraremos en detalle en estos temas, listando los problemas más frecuentes que encontramos durante el desarrollo de las mediciones:

- Criterio de selección de subcontratistas básicamente subordinado a la propuesta económica más barata.

- Visión corto-placista[ii] por parte del contratista general ya que sólo trata de obtener un beneficio esporádico en su obra a través de conseguir un precio barato para una actividad, sin valorar el efecto positivo de establecer algún tipo de relación estratégica a largo plazo con alguna de sus empresas subcontratistas.

- Poca participación del subcontratista en la planificación y toma de decisiones. Esta subordinación opaca la posibilidad de aprovechar la experiencia del subcontratista en su campo para beneficio de la obra.

- La falta de incentivos o la presencia de incentivos negativos. Por ejemplo el porcentaje del contrato que se retiene como garantía de que el trabajo se va a realizar conforme al contrato y en el plazo establecido es en algunos casos

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[ii] Se refiere a una visión centrada en la contratación de personal por el tiempo de duración del proyecto.

motivo de discusión. Y dado que todo el riesgo es asumido por el subcontratista, es éste quien suele llevar la peor parte.

Dentro del rubro de subcontratos, quisimos analizar de manera particular a aquellos que sólo aportan mano de obra, debido a que son los que tienen mayor participación en las obras:

Se aprecia en este tipo de subcontratistas mucha informalidad. La razón por la cual trabajar con estas empresas resulta más barato que trabajar con personal propio reside en que estas empresas no suelen tener a su gente en planilla (un operario contratado en planilla suele costar hasta 50% más que uno subcontratado). Dado el bajo precio con el que ganan, se ven obligados a buscar la manera de obtener ganancias de cualquier forma, siendo lo usual:

- Pagando menos a sus trabajadores.

- Contratando personal de menor categoría de la requerida dado que es más barato.

- Contratando mano de obra no especializada. Esto es que una misma persona de una categoría determinada puede estar realizando distintas labores como por ejemplo de carpintero, de fierrero, entre otras.

- Es mucho más importante la producción ya que como se les suele pagar a todo costo (un precio fijo por una tarea establecida) y no por horas hombres, les conviene terminar su labor de la forma más rápida posible. Esto puede comprometer otras actividades por ejemplo cuando se trabaja con un tren de obra en donde es necesario respetar la secuencia de avance.

- El mismo hecho de querer acabar su actividad de forma apresurada no les permite tener un control adecuado del uso de los materiales lo cual ocasiona pérdidas a los contratistas. Según un documento publicado por Lucio

Soibelman[iii] (2000) menciona que a mayor desperdicio se obtiene menor productividad.

- Además, definitivamente se va a ejercer una influencia negativa en la calidad. El hecho de tener trabajadores mal pagados ocasiona que se ejecuten las labores sólo por avanzar. Es por tal motivo que es muy importante el control porque de esa forma se pueden identificar y prever problemas posteriores.

iii Lucio Soibelman presentó el documento "Material de desperdicio en la industria de la construcción: incidencia y control" en la conferencia presentada en el VII Simposium de Ingeniería Civil, en el Instituto Tecnológico y de Estudios Superiores de Monterrey, Méjico, en Marzo del 2000

VI. CONCLUSIONES Y RECOMENDACIONES

El tema de productividad se ha hecho más conocido en los últimos años, pero son muy pocas las empresas que la aplican constantemente a fin de aprovechar mejor sus recursos. El mercado de la construcción se ha incrementado y con él, han surgido nuevas pequeñas empresas, las cuales normalmente están encabezadas por algún inversionista que no es ingeniero civil o desconoce del tema y, por lo tanto, carece del interés profesional en los temas de productividad y en su aplicación para la reducción de costos de construcción. Generalmente se realiza simplemente un estudio económico a corto plazo sin considerar que es mejor establecer una relación costo – beneficio a largo plazo en donde se evalúen los pros y contras de una propuesta dada.
Si bien hemos definido productividad en relación a la mano de obra, es necesario comprender que dicho término es bastante más amplio y que en sí el ser más productivo consiste en eliminar la mayor cantidad de pérdidas a fin de obtener un mejor resultado: ganar más dinero.
Por citar un ejemplo, puede resultar más económico el contratar a un ingeniero de campo dedicado a evaluar temas de manejo de producción y de personal; en lugar de prescindir de él y dejar a la obra sin control o al mando de personal no capacitado. Esto último puede derivar en pérdidas “escondidas”, como trabajos rehechos, mayor uso de materiales y mano de obra en dichos trabajos, insatisfacción del cliente, servicio post-venta continuo, etc.
Las conclusiones que se presentan a continuación enfocan los 2 temas analizados (Tipo de Estructura y Nivel de Integración de los Subcontratos) tomando como punto de referencia y objetivo fundamental la mejora en la productividad.

1. Respecto al Tipo de estructura

Pese a que asumimos que las obras de placas de concreto iban a obtener un mayor tiempo productivo debido a que éstas facilitaban el proceso constructivo, se observó que en realidad no difiere en mucho el construir un edificio de forma aporticada, en comparación con los edificios de muros de albañilería o con placas de concreto.

Dentro de las causas posibles de este resultado tenemos:

- Las obras de albañilería suelen tener mayor tiempo productivo debido a que cuando se analizaba al personal que asentaba ladrillos, éste realizaba dicha labor constantemente sin necesidad de realizar muchos viajes ni transportes lo que se veía reflejado en un mayor tiempo productivo. Además las obras de albañilería eran por lo general obras pequeñas.

- Las obras de concreto por lo general eran obras más grandes. Se analizaron obras de varios pisos, como obras que incluían varios módulos de edificios más pequeños. Esto ocasionaba que las mediciones arrojaban altos porcentajes en transportes y viajes debido al tamaño del proyecto.

Estos dos puntos podrían indicar que para este caso particular se requiere de un mayor detalle en la forma de la obtención de los datos ya que se aprecia claramente la influencia del tamaño de la obra, la forma del terreno, entre otros.

Por otro lado, salvando las limitaciones del indicador escogido para analizar la productividad, se puede afirmar a partir de lo observado en las visitas que las estructuras no se están diseñando bajo el concepto de constructabilidad, de modo de hacer más fácil la construcción del edificio.

Para remediar esto, es importante designar al ingeniero residente del proyecto desde la concepción del mismo, de modo que pueda participar en la elaboración de los planos desde la arquitectura. Su experiencia en construcción podrá ayudar a detectar errores en el papel antes de sorprenderse en obra y a que el diseño final resulte más económico para construir. La compatibilización de los planos de las instalaciones con la estructura y la arquitectura también debería llevarla a cabo él mismo en conjunto con los especialistas involucrados.

También es importante resaltar que la mayoría de construcciones visitadas estaban relacionadas con el programa Mi Vivienda, el cual propone brindar al público viviendas a un bajo costo.
Tendiendo esta premisa, es necesario el compromiso de los arquitectos de plantear diseños que promuevan el uso de sistemas constructivos sencillos y rápidos. Esto es, diseñando ambientes modulares que permitan el uso de alguna tecnología en particular (por decir el uso de ambientes de dimensiones múltiplos de 60 cm de modo de poder utilizar encofrado metálico de dicha dimensión) o de algún material de

acabado específico (por ejemplo ya que los muros pueden ser múltiplos de 60 cm, se puede utilizar algún cerámico de 30 x 30 a fin de eliminar retazos, cortes y facilitar la colocación de las piezas). También es preciso establecer la mayor simetría posible respecto de los ejes principales de la estructura para poder utilizar la misma cantidad de recursos en cada sector escogido así como para desarrollar la curva de aprendizaje del personal ya que a partir de estructuras simétricas se puede alcanzar una mayor cantidad de actividades repetitivas.

1. Respecto al Nivel de Integración de los subcontratos

En líneas generales y tras analizar los resultados obtenidos se aprecia que existe una relación directa entre el grado de integración y la productividad de la mano de obra lo cual confirma nuestra hipótesis referente a este tema.

Si observamos la Tabla Nº13A se puede observar que la mayoría de empresas (80.73 %) se encuentra clasificada como TIPO III, lo cual no es muy alentador. Sin embargo nos indica que tenemos un gran potencial de desarrollo en este tema.

De todos lo problemas encontrados y mencionados en el capítulo anterior referente a la identificación y descripción de las pérdidas encontradas, el tema del criterio de selección es el que consideramos más importante.

Por lo general la propuesta más económica suele ser la ganadora, lo cual creemos, bajo ciertas consideraciones, correcto y lógico. La diferencia radica en los criterios de evaluación que se contemplan, vale decir, en lo que el cliente valora y por lo que está dispuesto a pagar.

Como se menciona en palabras de John Ruskin (1860) en el reporte Accelerating Change: “Es tonto pagar demasiado, pero es peor pagar muy poco. Cuando pagas mucho se pierde un poco de dinero y eso es todo. Cuando pagas poco, algunas veces puedes perderlo todo, porque lo adquirido es incapaz de cumplir el objetivo para el que fue comprado. La ley común del equilibrio de los negocios prohíbe pagar poco y perder mucho. Si optas por la propuesta más económica, es conveniente agregar algo por el riesgo que se corre. Si haces esto, tendrás suficiente para pagar por algo mejor”.

Esto quiere decir que se debe poner mayor énfasis en el modo de selección de las subcontratas con las que se va a trabajar.

En un estudio realizado en Chile por Sergio Maturana, Luis Alarcón y Mladen Vrsalovic, en donde se muestran características de la relación con los subcontratistas muy similares a las de nuestra realidad, se propone un sistema de evaluación en campo en donde se pone énfasis a los siguientes puntos:

- La participación de los subcontratistas debe iniciarse antes de la formulación del plan maestro del proyecto a fin de poder aprovechar su conocimiento.

- Una vez iniciados los trabajos, se debe realizar una evaluación continua de la labor de cada subcontratista, al final de la cual se les debe de transmitir los resultados obtenidos a fin de crear retroalimentación en el proceso de conocimiento y poder producir mejoras. Incluso menciona que se debería crear una herramienta de visualización en donde se puedan observar los resultados de la evaluación, a fin de estimular la competitividad entre los subcontratistas y promover una acción proactiva en lugar de reactiva por parte de los mismos. Esta herramienta debe actuar como un recordatorio y como un medio de difusión de información. Además debe ser fácil de interpretar ya que de ello dependerá el efecto que tenga en la gente.

- Es necesario establecer un criterio adecuado para medir el desempeño. Aquí en Perú, en donde no existe una cultura de mediciones, un análisis subjetivo es adecuado.

- Es recomendable establecer un sistema de premios para los subcontratistas con mejor desempeño. Esto favorecerá la competencia entre ellos y mejorará su desempeño.

- Es muy importante la comunicación para mantener la coordinación entre las partes involucradas.

La aplicación de estos criterios favorecerán el desempeño de los integrantes del equipo, permitirán identificar mejoras para la administración de subcontratas, generará una base de datos con sus desempeños y fomentará la aplicación de benchmarking[i].

En resumidas cuentas esta propuesta engloba las características mostradas para el TIPO I en nuestra clasificación de subcontratos. Lo que falta recalcar es la ventaja que conlleva mantener una relación a largo plazo como lo propone el concepto del Partnering. Los subcontratistas seleccionados bajo el sistema de clasificación y evaluación propuesto permitirán, como se menciona, un desarrollo para ambas partes.

Sin embargo, algo que no se menciona en dicha investigación pero que consideramos de vital importancia es que el contratista debe participar como un ente regulador y organizador de todas las labores de los subcontratistas ya que, es inevitable que cada uno de los participantes del proyecto tienda a buscar su propio beneficio lo cual puede significar que perjudique de alguna u otra forma los trabajos de los demás.

Es pues el contratista general, quien debe encargarse de llevar las riendas del proyecto y de procurar que la labor de cada uno de los involucrados funcione como piezas de engranaje, todos orientados hacia un mismo fin. Para esto son muy importantes las herramientas propuestas por Ballard, tales como el Look Ahead Planning o la programación semanal, las cuales tienen como fin proporcionar confiabilidad a la programación de la obra bajo un concepto muy sencillo: para que una actividad pueda llevarse a cabo, deben superarse todas sus restricciones.

[i] El **benchmark** es una técnica utilizada para medir el rendimiento de un sistema o parte de un sistema, frecuentemente en comparación con algún parámetro de referencia. También puede encontrarse como benchmarking, el cual se refiere específicamente a la acción de ejecutar un benchmark.

2. Propuestas para investigaciones futuras

Como se ha mencionado repetidas veces en este proyecto, si bien se justifica el uso de un método subjetivo para la medición de la productividad, seria recomendable implementar un sistema de medición más específico de modo de poder obtener resultados más concretos.

Ya en otros países se ha tomado la iniciativa mediante la formación de instituciones encargadas de realizar la toma de datos y de publicar los resultados con el fin de crear conocimiento. Por ejemplo en el Reino Unido, las empresas DTI (Department of Trade and Industry) y CBPP (Construction Best Practice Programme) realizan anualmente publicaciones de los resultados tales como productividad entre otros en dicho país. Con esto se logra tener no sólo un historial del desarrollo del indicador analizado sino que se puede reconocer el efecto directo de alguna práctica establecida.

Esto se realiza a través de los llamados “proyectos de demostración” (demonstration projects) con el fin de aplicar alguna propuesta dada, analizar los resultados y publicarlos a fin de tener respuestas concretas.

De la misma forma se podría actuar aquí, aplicando las propuestas establecidas en este proyecto, analizando los resultados e identificando si se ha generado alguna mejora.

Este tipo de metodología de generación de conocimiento también sería útil para comparar procedimientos o para discernir entre la aplicación de alguna tecnología específica en un caso determinado.

Para esto no sólo se requiere del apoyo de instituciones privadas sino también del estado.

Lamentablemente, algo que pudimos observar durante nuestra investigación es el recelo que poseen algunas de las empresas a que se divulguen sus procedimientos utilizados o su metodología para dirigir el proyecto. La negativa de las empresas dificultaba la toma de datos ya que se perdía mucho tiempo buscando de personas interesadas que apoyen al proyecto.

Si es que de verdad queremos generar un cambio en la forma como se construye en nuestro país, es necesario que todos los involucrados colaboremos, que en la medida de lo posible compartamos nuestras experiencias para que a largo plazo nos veamos beneficiados todos.

Consideramos que para resolver muchos de los problemas que surgen en obra, no es necesario descubrir la pólvora ya que probablemente dichos problemas ya se han presentado en algún otro proyecto.

Por otra parte, se encontró un punto en el que el IP requiere de mayor detalle para obtener un resultado más real, desde el punto de vista de la productividad de mano de obra. Para salvar este inconveniente es necesario realizar una subclasificación de los tipos de estructura, haciendo la diferenciación según el tamaño del terreno, cantidad pisos que tiene el edificio, etc. Es decir, para poder comparar, en términos de productividad, un sistema aporticado y uno de muros de concreto, debemos medirlos en condiciones iguales o similares.

Asimismo, se podría determinar si existe un punto de inflexión, es decir, un caso en el cual los dos sistemas tienen igual valor del IP, y en casos superiores e inferiores, es uno el que desataca sobre el otro.

En cuanto a subcontratos, se puede realizar la evaluación de los mismos con el nivel de detalle que utilizamos para la empresa contratista en la tesis presente. Es decir, evaluar la tecnología, gestión y productividad de distintas actividades que son subcontratadas, de modo de obtener una calificación final que indique al contratista la mejor opción para las exigencias de su proyecto.

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PONTIFICIA UNIVERSIDAD CATOLICA DEL PERU

FACULTAD DE CIENCIAS E INGENIERIA

"DIAGNOSTICO Y EVALUACION DEL TIPO DE ESTRUCTURA Y DEL GRADO DE INTEGRACION ENTRE SUBCONTRATISTA Y CONTRATISTA CON LA PRODUCTIVIDAD"

ANEXOS

CRISTHIAN CAÑA RAMOS
PEDRO A. ESCAJADILLO IRING

Lima, Agosto 2006

INDICE

ANEXO 01:

Justificación estadística de la muestra de obras tomada

El propósito de un estudio estadístico es extraer conclusiones acerca de la naturaleza de una población. Al ser la población grande y no poder ser estudiada en su integridad, se realiza el estudio a una parte de la población lo que denominamos "muestra".

Para el presente estudio partimos de que nuestra población son: LAS OBRAS DE EDIFICACIONES PARA VIVIENDA EN ETAPA DE CASCO ESTRUCTURAL realizadas en LIMA METROPOLITANA POR EMPRESAS FORMALMENTE CONSTITUIDAS, las cuales asumimos como INFINITAS.

A partir de los datos obtenidos en las mediciones, asumiendo una confiabilidad del 95%, fuimos calculando el error máximo; concluyendo que, con 26 obras logramos un error aceptable, como se muestra a continuación:

Cálculos Realizados

Para el cálculo del intervalo de confianza en una población normal como es la nuestra, tomamos como parámetros:

- Nivel de confiabilidad de 95%
- Coeficiente de confiabilidad $z_{1-\ /2} = 1.96$[1]
- Cantidad de datos tomados n = 26

Hallamos la desviación estándar de nuestra muestra, resultando:

$$\sigma = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2}$$ [2]

$$\boldsymbol{\sigma = 4.96\%}$$

[1] Coeficiente que depende del nivel de confiabilidad buscado, para este caso según tablas (que se pueden encontrar en el anexo) para un nivel de confiabilidad del 95% el coeficiente resulta **1.96**

[2] Estadística Aplicaciones Tercera Edición" *Carlos Veliz Capuñay*, Pág. 317

Al ser nuestra muestra infinita, hallamos el error máximo a partir de la siguiente fórmula

$$\varepsilon = \frac{\sigma}{\sqrt{n}} z_{1-\alpha/2} = \frac{4.96\%}{\sqrt{26}} 1.96 = 1.90\%$$ [3]

ε = 1.90%

Al analizar el error obtenido, podemos afirmar:

Que las obras de construcción en Lima Metropolitana que estuvieron en la etapa de casco estructural entre los meses de Abril y Agosto, tienen un porcentaje de trabajo productivo de 31.50%, con el 95% de confiabilidad de que este valor puede variar como máximo en 1.90%

Resumiendo:

El trabajo productivo en Lima esta entre los valores de 29.60% y 33.40%.

Tomemos en cuenta que para el presente estudio se asumió una cantidad infinita de obras, lo cual dista de la realidad. El cambio de una cantidad infinita a otra finita se reflejaría en una disminución del intervalo de variación.

Además el estudio actual fue realizado de manera estratificada, donde se dividió a la población en distritos, comenzando el análisis en los distritos de mayor incidencia de obras; datos que los obtuvimos a partir de páginas publicadas en el Portal de MiVivienda, este Tipo de Muestreo Estratificado, mejora la confiabilidad de los resultados.

[3] Estadística Aplicaciones Tercera Edición" *Carlos Veliz Capuñay*, Pág. 320

ANEXO 02:

Formatos empleados durante la investigación

Los formatos empleados son los siguientes:

1. Formato para la medición general de obra
2. Formato de Identificación de Obra
3. Formato Encuesta dirigido al personal técnico y administrativo
4. Formato Encuesta dirigida a obreros y capataces
5. Formato de entrevista para subcontratistas y proveedores
6. Formato de entrevista para subcontratistas pequeños

FORMATO PARA MEDICION GENERAL DE OBRA

Obra ______________________________ Clima: ______________

Fecha: ______________ Encargado de Medición: ______________________________

Inicio: ______________ Condiciones Iniciales: ______________________________

Fin: ______________ ______________________________

N°	CUADRILLA	TIPO	N°	CUADRILLA	TIPO	N°	CUADRILLA	TIPO	N°	CUADRILLA	TIPO
1			51			101			151		
2			52			102			152		
3			53			103			153		
4			54			104			154		
5			55			105			155		
6			56			106			156		
7			57			107			157		
8			58			108			158		
9			59			109			159		
10			60			110			160		
11			61			111			161		
12			62			112			162		
13			63			113			163		
14			64			114			164		
15			65			115			165		
16			66			116			166		
17			67			117			167		
18			68			118			168		
19			69			119			169		
20			70			120			170		
21			71			121			171		
22			72			122			172		
23			73			123			173		
24			74			124			174		
25			75			125			175		
26			76			126			176		
27			77			127			177		
28			78			128			178		
29			79			129			179		
30			80			130			180		
31			81			131			181		
32			82			132			182		
33			83			133			183		
34			84			134			184		
35			85			135			185		
36			86			136			186		
37			87			137			187		
38			88			138			188		
39			89			139			189		
40			90			140			190		
41			91			141			191		
42			92			142			192		
43			93			143			193		
44			94			144			194		
45			95			145			195		
46			96			146			196		
47			97			147			197		
48			98			148			198		
49			99			149			199		
50			100			150			200		

N°	CUADRILLA	TIPO	N°	CUADRILLA	TIPO	N°	CUADRILLA	TIPO	N°	CUADRILLA	TIPO
201			251			301			351		
202			252			302			352		
203			253			303			353		
204			254			304			354		
205			255			305			355		
206			256			306			356		
207			257			307			357		
208			258			308			358		
209			259			309			359		
210			260			310			360		
211			261			311			361		
212			262			312			362		
213			263			313			363		
214			264			314			364		
215			265			315			365		
216			266			316			366		
217			267			317			367		
218			268			318			368		
219			269			319			369		
220			270			320			370		
221			271			321			371		
222			272			322			372		
223			273			323			373		
224			274			324			374		
225			275			325			375		
226			276			326			376		
227			277			327			377		
228			278			328			378		
229			279			329			379		
230			280			330			380		
231			281			331			381		
232			282			332			382		
233			283			333			383		
234			284			334			384		
235			285			335			385		
236			286			336			386		
237			287			337			387		
238			288			338			388		
239			289			339			389		
240			290			340			390		
241			291			341			391		
242			292			342			392		
243			293			343			393		
244			294			344			394		
245			295			345			395		
246			296			346			396		
247			297			347			397		
248			298			348			398		
249			299			349			399		
250			300			350			400		

Observaciones ____

CÓDIGO:

FORMATO DE IDENTIFICACIÓN DE OBRA

(FIO)

TESISTA:
FECHA:

DE LA OBRA

NOMBRE: ____________________

DIRECCIÓN: ____________________

TELÉFONO: ____________ CORREO ELECTRÓNICO: ____________

DE LA EMPRESA CONSTRUCTORA

NOMBRE: ____________________

DIRECCIÓN: ____________________

TELÉFONO: ____________ CORREO ELECTRÓNICO: ____________

DEL INGENIERO RESIDENTE

NOMBRE: ____________________

TELÉFONO: ____________ CORREO ELECTRÓNICO: ____________

DEL PROYECTO

TIPO DE CONTRATO:

- ☐ Suma Alzada
- ☐ Administración Directa
- ☐ Precios Unitarios
- ☐ Constructora - Inmobiliaria
- ☐ Otros: ____________

TIPO DE ESTRUCTURA:

- ☐ Muros de concreto armado
- ☐ Albañilería Armada/Confinada
- ☐ Muros de ductilidad limitada
- ☐ Pórticos y tabiques
- ☐ Sistema Dual
- ☐ Otro

SECUENCIA DEL TRABAJO

Área de Losa llenada ____________ m^2 cada ____________ dias

INICIO: ____________ CANTIDAD DE OBREROS: ____________

DURACIÓN: ____________ AVANCE PROYECTO (CASCO): ____________

PERSONAL TÉCNICO Y ADMINISTRATIVO QUE PARTICIPA EN LA PLANIFICACION

- ☐ Ingeniero Residente
- ☐ Ingeniero Concreto
- ☐ Administrador
- ☐ Ingeniero Supervisor
- ☐ Ingeniero Costos
- ☐ Maestro de Obra
- ☐ Ingeniero Asistente
- ☐ Ingeniero Productividad
- ☐ Almacenero
- ☐ Otros:

DEL PERSONAL SUBCONTRATADO

INDIQUE EL MONTO APROXIMADO DE ACTIVIDADES SUBCONTRATADAS: ____________ %

CALIFIQUE USTED LOS PRINCIPALES PROBLEMAS CON LOS SUBCONTRATISTAS:

No realizan bien su trabajo, tienen muchos errores	1	2	3	4	5
Sólo les interesa el avance	1	2	3	4	5
Desperdician material, si no lo han aportado	1	2	3	4	5
Sus errores usualmente comprometen a otras actividades	1	2	3	4	5
No participan en el planificación	1	2	3	4	5
El personal de la casa y el subcontratado no se llevan bien	1	2	3	4	5
El pago a los subcontratistas es muy bajo	1	2	3	4	5
Otros: ____________	1	2	3	4	5

OTROS DATOS

ÁREA TOTAL DEL TERRENO: ________ ÁREA A CONSTRUIR: ________ Nº PISOS: ________

CANTIDAD DE DEPARTAMENTOS: ________ ÁREA DE DEP: ________ PRECIOS: ________

COSTO DE LA CONSTRUCCIÓN: ________ ÁREA DE DEP: ________ PRECIOS: ________

COMENTARIOS DEL TESISTA

DESCRIPCIÓN DEL PROYECTO: *(dptos por piso, descripción de la estructura.)*

____

____

____

NOTAS A LA ENTREVISTA: *(Comentarios y/o añadidos del Residente)*

____

____

____

PERSONAL SUBCONTRATADO	APORTE		CONTRATO		CONTROL			ANTIGÜEDAD
			EL CONTRATO INCLUYE:		CONTROL A PARTIR DE:		FRECUENCIA	CANTIDAD DE PROYECTOS
☐ Carpintería	☐ Mano de Obra ☐ Materiales ☐ Diseño	☐ Mantenimiento ☐ ____________	☐ Monto y Plazo ☐ Metrado ☐ Especificaciones	☐ Sanciones y/o Premios ☐ Otros:____________________ ☐ No hay Contrato	☐ Avance ☐ Recursos ☐ Costos	☐ Productividad ☐ Otros__________ ☐ No hay Control	☐ Diario ☐ Semanal ☐ Quincenal	☐ Primero ☐ Segundo ☐ Más de 2
☐ Acero	☐ Mano de Obra ☐ Materiales ☐ Diseño	☐ Mantenimiento ☐ ____________	☐ Monto y Plazo ☐ Metrado ☐ Especificaciones	☐ Sanciones y/o Premios ☐ Otros:____________________ ☐ No hay Contrato	☐ Avance ☐ Recursos ☐ Costos	☐ Productividad ☐ Otros__________ ☐ No hay Control	☐ Diario ☐ Semanal ☐ Quincenal	☐ Primero ☐ Segundo ☐ Más de 2
☐ Inst. Eléctricas	☐ Mano de Obra ☐ Materiales ☐ Diseño	☐ Mantenimiento ☐ ____________	☐ Monto y Plazo ☐ Metrado ☐ Especificaciones	☐ Sanciones y/o Premios ☐ Otros:____________________ ☐ No hay Contrato	☐ Avance ☐ Recursos ☐ Costos	☐ Productividad ☐ Otros__________ ☐ No hay Control	☐ Diario ☐ Semanal ☐ Quincenal	☐ Primero ☐ Segundo ☐ Más de 2
☐ Inst. Sanitarias	☐ Mano de Obra ☐ Materiales ☐ Diseño	☐ Mantenimiento ☐ ____________	☐ Monto y Plazo ☐ Metrado ☐ Especificaciones	☐ Sanciones y/o Premios ☐ Otros:____________________ ☐ No hay Contrato	☐ Avance ☐ Recursos ☐ Costos	☐ Productividad ☐ Otros__________ ☐ No hay Control	☐ Diario ☐ Semanal ☐ Quincenal	☐ Primero ☐ Segundo ☐ Más de 2
☐ Inst. Mecánicas	☐ Mano de Obra ☐ Materiales ☐ Diseño	☐ Mantenimiento ☐ ____________	☐ Monto y Plazo ☐ Metrado ☐ Especificaciones	☐ Sanciones y/o Premios ☐ Otros:____________________ ☐ No hay Contrato	☐ Avance ☐ Recursos ☐ Costos	☐ Productividad ☐ Otros__________ ☐ No hay Control	☐ Diario ☐ Semanal ☐ Quincenal	☐ Primero ☐ Segundo ☐ Más de 2
☐ Estr. Metálicas	☐ Mano de Obra ☐ Materiales ☐ Diseño	☐ Mantenimiento ☐ ____________	☐ Monto y Plazo ☐ Metrado ☐ Especificaciones	☐ Sanciones y/o Premios ☐ Otros:____________________ ☐ No hay Contrato	☐ Avance ☐ Recursos ☐ Costos	☐ Productividad ☐ Otros__________ ☐ No hay Control	☐ Diario ☐ Semanal ☐ Quincenal	☐ Primero ☐ Segundo ☐ Más de 2
☐ Mov. de Tierras	☐ Mano de Obra ☐ Materiales ☐ Diseño	☐ Mantenimiento ☐ ____________	☐ Monto y Plazo ☐ Metrado ☐ Especificaciones	☐ Sanciones y/o Premios ☐ Otros:____________________ ☐ No hay Contrato	☐ Avance ☐ Recursos ☐ Costos	☐ Productividad ☐ Otros__________ ☐ No hay Control	☐ Diario ☐ Semanal ☐ Quincenal	☐ Primero ☐ Segundo ☐ Más de 2
☐ Albañilería	☐ Mano de Obra ☐ Materiales ☐ Diseño	☐ Mantenimiento ☐ ____________	☐ Monto y Plazo ☐ Metrado ☐ Especificaciones	☐ Sanciones y/o Premios ☐ Otros:____________________ ☐ No hay Contrato	☐ Avance ☐ Recursos ☐ Costos	☐ Productividad ☐ Otros__________ ☐ No hay Control	☐ Diario ☐ Semanal ☐ Quincenal	☐ Primero ☐ Segundo ☐ Más de 2
☐ Tarrajeo	☐ Mano de Obra ☐ Materiales ☐ Diseño	☐ Mantenimiento ☐ ____________	☐ Monto y Plazo ☐ Metrado ☐ Especificaciones	☐ Sanciones y/o Premios ☐ Otros:____________________ ☐ No hay Contrato	☐ Avance ☐ Recursos ☐ Costos	☐ Productividad ☐ Otros__________ ☐ No hay Control	☐ Diario ☐ Semanal ☐ Quincenal	☐ Primero ☐ Segundo ☐ Más de 2
☐ Mayólicas	☐ Mano de Obra ☐ Materiales ☐ Diseño	☐ Mantenimiento ☐ ____________	☐ Monto y Plazo ☐ Metrado ☐ Especificaciones	☐ Sanciones y/o Premios ☐ Otros:____________________ ☐ No hay Contrato	☐ Avance ☐ Recursos ☐ Costos	☐ Productividad ☐ Otros__________ ☐ No hay Control	☐ Diario ☐ Semanal ☐ Quincenal	☐ Primero ☐ Segundo ☐ Más de 2
☐ ____________	☐ Mano de Obra ☐ Materiales ☐ Diseño	☐ Mantenimiento ☐ ____________	☐ Monto y Plazo ☐ Metrado ☐ Especificaciones	☐ Sanciones y/o Premios ☐ Otros:____________________ ☐ No hay Contrato	☐ Avance ☐ Recursos ☐ Costos	☐ Productividad ☐ Otros__________ ☐ No hay Control	☐ Diario ☐ Semanal ☐ Quincenal	☐ Primero ☐ Segundo ☐ Más de 2
☐ ____________	☐ Mano de Obra ☐ Materiales ☐ Diseño	☐ Mantenimiento ☐ ____________	☐ Monto y Plazo ☐ Metrado ☐ Especificaciones	☐ Sanciones y/o Premios ☐ Otros:____________________ ☐ No hay Contrato	☐ Avance ☐ Recursos ☐ Costos	☐ Productividad ☐ Otros__________ ☐ No hay Control	☐ Diario ☐ Semanal ☐ Quincenal	☐ Primero ☐ Segundo ☐ Más de 2

PONTIFICIA UNIVERSIDAD CATÓLICA DEL PERÚ

TECNOLOGÍAS EN LA OBRA

RUBRO / TECNOLOGÍA		¿ LO TIENE?	CANTIDAD	¿NECESITA?
ACERO				
CONVENCIONAL	________	☐	________	☐
DIMENSIONADO	________	☐	________	☐
MALLA ELECTROSOLDADA (MURO)	________	☐	________	☐
MALLA ELECTROSOLDADA (TECHO)	________	☐	________	☐
OTROS:		☐		☐
ENCOFRADOS			________	
ENCOFRADO METÁLICO	________	☐	________	☐
OTROS:		☐		☐
CONCRETO (PREPARACIÓN)				
MEZCLADORA ESTACIONARIA	________	☐	________	☐
CONCRETO PREMEZCLADO	________	☐	________	☐
CONCRETO PREFABRICADO	________	☐	________	☐
CONCRETO POSTENSADO	________	☐	________	☐
CONCRETO PRETENSADO	________	☐	________	☐
ADITIVOS	________	☐	________	☐
	________		________	
	________		________	
OTROS:		☐		☐
CONCRETO (VACIADO)				
BOMBA ESTACIONARIA	________	☐	________	☐
BOMBA MÓVIL	________	☐	________	☐
BALDE	________	☐	________	☐
GRÚA	________	☐	________	☐
VIBRADOR (GASOLINA O ELÉCTRICO)	________	☐	________	☐
OTROS:		☐		☐
MOVIMIENTO DE TIERRAS				
CARGADOR FRONTAL	________	☐	________	☐
RETROEXCAVADORA	________	☐	________	☐
MOTO NIVELADORA	________	☐	________	☐
VOLQUETE	________	☐	________	☐
OTROS:		☐		☐
TRANSPORTE DE MATERIALES				
WINCHE	________	☐	________	☐
ELEVADOR VERTICAL	________	☐	________	☐
GRÚA	________	☐	________	☐
DUMPER	________	☐	________	☐
OTROS:		☐		☐
COMUNICACIONES				
NEXTEL O SIMILARES:	________	☐	________	☐
CORREO ELECTRÓNICO:	________	☐	________	☐
OTROS:		☐		☐
SOFTWARE				
CONTROL DE OBRA	________	☐	________	☐
PROGRAMACIÓN DE OBRA	________	☐	________	☐
OTROS:		☐		☐
OTROS:				
SISTEMA DE ELIMINACIÓN BASURA	________	☐	________	☐
ESPECIFICAR:	________	☐	________	☐
OTROS:		☐		☐

COMENTARIOS:

____

____

____

____

____

AGENDA DE VISITA A OBRA:

ACTIVIDADES:		CÓDIGO	VECES
MEDICIÓN DE NIVEL GENERAL DE OBRA		NGO	5
MEDICIÓN DE NIVEL GENERAL DE ACTIVIDAD:	________________	NGA	INDICAR: _____
	________________	NGA	INDICAR: _____
	________________	NGA	INDICAR: _____
FORMATO DE IDENTIFICACIÓN DE OBRA Y RESIDENTE		FIO	1
FORMATO DE ENCUENTA PARA PERSONAL TÉCNICO Y ADMINISTRATIVO (PLANIFICACIÓN)		FEPETA	INDICAR: _____
FORMATO DE ENCUENTA PARA PERSONAL OBRERO Y CAPATACES		FEDOC	8

SEMANA 1

LUNES ☐	MARTES ☐	MIÉRCOLES ☐	JUEVES ☐	VIERNES ☐	SÁBADO ☐
HORA: ______	HORA: ______	HORA: ______	HORA: ______	HORA: ______	HORA: ______
ACTIVIDAD: ______	ACTIVIDAD: ______	ACTIVIDAD: ______	ACTIVIDAD: ______	ACTIVIDAD: ______	ACTIVIDAD: ______
HORA: ______	HORA: ______	HORA: ______	HORA: ______	HORA: ______	HORA: ______
ACTIVIDAD: ______	ACTIVIDAD: ______	ACTIVIDAD: ______	ACTIVIDAD: ______	ACTIVIDAD: ______	ACTIVIDAD: ______
HORA: ______	HORA: ______	HORA: ______	HORA: ______	HORA: ______	HORA: ______
ACTIVIDAD: ______	ACTIVIDAD: ______	ACTIVIDAD: ______	ACTIVIDAD: ______	ACTIVIDAD: ______	ACTIVIDAD: ______

SEMANA 2

LUNES ☐	MARTES ☐	MIÉRCOLES ☐	JUEVES ☐	VIERNES ☐	SÁBADO ☐
HORA: ______	HORA: ______	HORA: ______	HORA: ______	HORA: ______	HORA: ______
ACTIVIDAD: ______	ACTIVIDAD: ______	ACTIVIDAD: ______	ACTIVIDAD: ______	ACTIVIDAD: ______	ACTIVIDAD: ______
HORA: ______	HORA: ______	HORA: ______	HORA: ______	HORA: ______	HORA: ______
ACTIVIDAD: ______	ACTIVIDAD: ______	ACTIVIDAD: ______	ACTIVIDAD: ______	ACTIVIDAD: ______	ACTIVIDAD: ______
HORA: ______	HORA: ______	HORA: ______	HORA: ______	HORA: ______	HORA: ______
ACTIVIDAD: ______	ACTIVIDAD: ______	ACTIVIDAD: ______	ACTIVIDAD: ______	ACTIVIDAD: ______	ACTIVIDAD: ______

Horarios para las Encuestas:
FEPETA: ____________
FEDOC: ____________

OBSERVACIONES Y/O RECOMENDACIONES: *(Comentarios y/o añadidos del Tesista)*

____
____
____

FORMATO ENCUESTA DIRIGIDA AL PERSONAL TÉCNICO Y ADMINISTRATIVO

(FEPETA)

(NO LLENAR)

CÓDIGO DE LA OBRA: ____________ **NUMERO ENCUESTA:** ______

(ESTA ENCUESTA ES TOTALMENTE ANÓNIMA Y ES PROPIEDAD DEL GRUPO DE TESIS)

PLANIFICACIÓN Y EJECUCIÓN DEL PROYECTO

1. INDIQUE EL CARGO QUE DESEMPEÑA EN LA EMPRESA: ____________________

2. ¿QUÉ TIPO DE PLANIFICACIÓN SE REALIZA EN LA OBRA Y QUE COMPRENDE CADA UNA?

- ☐ General ____________________
- ☐ Mediano Plano ____________________
- ☐ Corto Plazo ____________________
- ☐ Otro ____________________

3. ¿CÓMO SE TRANSMITE LA INFORMACIÓN DE LA PLANIFICACIÓN A LOS JEFES DE OBRA? (verbal o escrita)

Nivel de detalle	Maestro	Capataces
Recursos a utilizar		
Lugar de trabajo		
Plazo		
Otros		

4. ¿SE DISEÑAN PROCEDIMIENTOS CONSTRUCTIVOS Y CUÁLES SON?

- ☐ Ninguno
- ☐ Solo los procedimientos complicados ____________________
- ☐ Las partidas con alta incidencia en el presupuesto ____________________
- ☐ Algunas operaciones como: ____________________

4.1 ¿QUIÉN O QUIENES SON LOS ENCARGADOS DEL DISEÑO?

- ☐ Residente ☐ Otro: ____________________
- ☐ Maestro de Obra

5. ¿QUIÉN ESTÁ ENCARGADO DE PLANIFICAR LA UTILIZACIÓN DE LOS RECURSOS? *(marque con un CHECK)*

CARGO	M.O.	MAT.	EQUIPO
Ingeniero Residente			
Ingeniero Asistente			
Administrador			
Maestro			
Otro:			

6. ¿A PARTIR DE QUE INFORMACIÓN SE REALIZA LA PLANIFICACIÓN?

- ☐ Según experiencia del Residente
- ☐ Por rendimientos mínimos
- ☐ Por rendimientos históricos de la empresa
- ☐ Otros: ____________________

7. ¿QUIÉN ES EL ENCARGADO DE LA DISTRIBUCIÓN DE RECURSOS?

- ☐ Solo el Maestro de Obra
- ☐ El Maestro de Obra en coordinación con el residente
- ☐ Otros: ____________________

SEGUIMIENTO Y CONTROL

1. REALIZA CONTROLES EN LA OBRA

☐ Si ☐ No

SI LA RESPUESTA ES SI, ¿CÓMO LO CONTROLA?

MODO DE CONTROL	FRECUENCIA			
	SEMANAL	QUINCENAL	MENSUAL	AL FINAL
☐ Informe de costos				
☐ Informes de avance				
☐ Recorridos por la obra				
☐ Reuniones				
☐ Informe de productividad				
☐ Informe de calidad				
☐ Otros:______________				
☐ Otros:______________				

2. ¿ES ACTUALIZADA LA PLANIFICACIÓN DESPUÉS QUE SE REALIZA?

☐ Si
☐ No

SI LA RESPUESTA ES NO, ¿POR QUE? ____

SI LA RESPUESTA ES SI, ¿CON QUE FRECUENCIA?

☐ Diariamente ☐ Semanalmente ☐ Otro: ______________________

A PARTIR DE QUE DATOS SE EJECUTA LA ACTUALIZACIÓN DE LA PLANIFICACIÓN

☐ Rendimientos ☐ Avance ☐ Otro: ______________________

3. SI SURGE UN ATRASO, USUALMENTE SE SOLUCIONA:

☐ Haciendo que los trabajadores se queden horas extra
☐ Trabajando los Domingo y/o feriados
☐ Se acepta el atraso y se hace una nueva planificación
☐ Otro: ____

4. ¿EN QUE ACTIVIDADES SE CONSUME LA MAYOR CANTIDAD DE HORAS EXTRA?

☐ Vaciado de concreto ☐ Habilitación material ☐ Inst. Sanitarias / Eléctricas
☐ Encofrado ☐ Colocación Acero ☐ Otro: ______________________

5. ¿CUAL O CUALES CREE USTED QUE SON LOS PROBLEMAS MAS COMUNES QUE GENERAN LOS ATRASOS?

(marque con un CHECK)

PROBLEMA	
Abastecimiento	
Descoordinaciones	
Subcontratos	
Rendimientos, (mdo)	
Sindicatos	
Maquinaria	
Otros:___________________________________	

6. CUANDO LOS PROBLEMAS SON DESCUBIERTOS, SE PROCEDE A:

☐ Reparar los defectos y seguir adelante
☐ Se averiguan las causas del problema y se actúa para prevenir problemas futuros
☐ Aclaramos el porqué no nos dimos cuenta temprano y rediseñamos la forma de ejecutar el trabajo para poder actuar rápido sobre problemas similares en el futuro.
☐ Analizamos el problema y lo tomamos como experiencia para el futuro
☐ Identificamos a responsable y tomamos las medidas respectivas
☐ Otros:____

7. ¿REALIZAN CHARLAS DE CAPACITACIÓN AL PERSONAL?

☐ Si ☐ No

8. CON QUE FRECUENCIA SE REALIZAN

☐ Semanales ☐ Diarias
☐ Mensuales ☐ Otras ______________________

FORMATO ENCUESTA DIRIGIDA A OBREROS Y CAPATACES

(FEDOC)

Encargado de la mediciòn: ____________________ *Fecha* ____________________

Hora ____________________

(NO LLENAR)

CÓDIGO DE LA OBRA: [ ] **NUMERO ENCUESTA:** [ ]

(ESTA ENCUESTA ES TOTALMENTE ANÓNIMA Y ES PROPIEDAD DEL GRUPO DE TESIS)

1. INDIQUE LA CUADRILLA A LA QUE PERTENECE
   - ☐ Concreto ☐ Encofrado ☐ Acero
   - ☐ Albañilería ☐ Revoques ☐ Otro: ____________________

2. INDIQUE SU RANGO:
   - ☐ Peón ☐ Oficial ☐ Operario
   - ☐ Capataz ☐ Otro: ____________________

3. INDIQUE SU SISTEMA DE TRABAJO
   - ☐ Por avance (jornada) Horario ____________________
   - ☐ Por tareas
     - ☐ 40 o menos
     - ☐ Entre 40 o 50
     - ☐ 50 o menos
   - ☐ Otro: ____________________

5. ¿TRABAJA HORAS EXTRA? ☐ Si ☐ No

   SI TRABAJA HORAS EXTRA, ¿CUANTAS SEMANALMENTE? ____________________

6. USTED ES PERSONAL SUBCONTRATADO
   - ☐ Si ☐ No

7. SI USTED ES PERSONAL SUBCONTRATADO:

   7.1. SI USTED ES PERSONAL SUBCONTRATADO, ¿HA TRABAJADO ANTES CON LA MISMA EMPRESA?
   - ☐ Si, llevamos trabajando varios proyectos ☐ No, este es el primer proyecto
   - ☐ Si, este es el segundo proyecto juntos

   7.2. SI USTED ES PERSONAL SUBCONTRATADO, MARQUE LOS PROBLEMAS MAS FRECUENTES:
   - ☐ No estoy enterado del contrato que se firmó con el contratista o éste no existe
   - ☐ No me pagan lo adecuado
   - ☐ No me pagan a tiempo
   - ☐ El personal "de la casa" es hostil
   - ☐ Otros: ______________________________

8. PRESENTA ALGÚN PROBLEMA CON LOS MATERIALES
   - ☐ Si ☐ No

9. EN CASO TENGA ALGÚN PROBLEMA CON LOS MATERIALES:

   9.1. ¿QUÉ HACE SI NO TIENE MATERIAL A LA MANO?
   - ☐ Lo busco en almacén ☐ Se lo comunico al Jefe de cuadrilla
   - ☐ Debo esperarlo ☐ Se lo comunico al Maestro de Obra
   - ☐ Hago otra labor ☐ Se lo comunico al Ingeniero
   - ☐ Otros: ______________________________

9.2. ¿CUÁNTO TIEMPO A LA SEMANA CALCULA QUE PIERDE POR NO TENER SUS MATERIALES A LA MANO?

- ☐ Menos de 1 hora
- ☐ De 4 a 7 horas
- ☐ De 1 a 3 horas
- ☐ Más de 7 horas

9.3. ¿POR QUÉ CREE USTED QUE NO TIENE LISTOS SUS MATERIALES?

- ☐ El material no llega a la obra a tiempo
- ☐ Debo esperar que la grúa/winche lo transporte
- ☐ El material no está en almacén
- ☐ Otros: ______________________
- ☐ No se me informa la labor que debo realizar

9.4. SI DEPENDIESE DE USTED, ¿CÓMO ARREGLARÍA LA FALTA DE MATERIALES?

- ☐ Delegaría a alguien la tarea de observar qué materiales se requerirán para las labores del día siguiente
- ☐ Pediría que los materiales estén en obra con suficiente anticipación
- ☐ Planificaría las labores diarias de cada cuadrilla, para evitar problemas de abastecimiento de materiales
- ☐ Otros: ______________________

10. TIENE ALGÚN PROBLEMA CON LAS HERRAMIENTAS:

- ☐ Si
- ☐ No

11. EN CASO PRESENTE ALGÚN PROBLEMA CON LAS HERRAMIENTAS:

11.1. ¿QUÉ HACE SI NO TIENE SUS HERRAMIENTAS O EQUIPOS A LA MANO?

- ☐ Lo busco en almacén
- ☐ Se lo comunico al Jefe de cuadrilla
- ☐ Debo esperar que dejen de utilizarlo
- ☐ Se lo comunico al Maestro de Obra
- ☐ Hago otra labor
- ☐ Se lo comunico al Ingeniero
- ☐ Otros:______________________

11.2. ¿CUÁNTO TIEMPO A LA SEMANA CALCULA QUE PIERDE POR NO TENER SUS HERRAMIENTAS A LA MANO?

- ☐ Menos de 1 hora
- ☐ De 4 a 7 horas
- ☐ De 1 a 3 horas
- ☐ Más de 7 horas

11.3. ¿POR QUÉ CREE USTED QUE NO TIENE LISTAS SUS HERRAMIENTAS Y/O EQUIPOS?

- ☐ Las está utilizando otra cuadrilla / obrero
- ☐ Debo esperar que la grúa/winche los transporte
- ☐ Las herramientas no está en almacén
- ☐ Otros: ______________________
- ☐ No se me informa la labor que debo realizar

11.4. SI DEPENDIESE DE USTED, ¿CÓMO ARREGLARÍA LA FALTA DE HERRAMIENTAS Y/O EQUIPOS?

- ☐ Delegaría a alguien la tarea de observar qué herramientas se requerirán para las labores del día siguiente
- ☐ Compraría o alquilaría más herramientas o equipos
- ☐ Planificaría las labores diarias de cada cuadrilla, para evitar problemas de abastecimiento de los equipos
- ☐ Otros: ______________________

12. ¿CON CUÁLES DE SUS SUPERIORES TIENE MAYOR COMUNICACIÓN?

- ☐ Jefe de cuadrilla
- ☐ Maestro de Obra
- ☐ Ingeniero Asistente
- ☐ Capataz
- ☐ Ingeniero Residente
- ☐ Otro: ______________

13. A SU PARECER, CUÁNDO OCURRE UN PROBLEMA, ¿QUIEN LO RESUELVE?

- ☐ Jefe de cuadrilla
- ☐ Maestro de Obra
- ☐ Ingeniero Asistente
- ☐ Capataz
- ☐ Ingeniero Residente
- ☐ Otro: ______________

14. ¿A QUÉ HORA DE LA MAÑANA SE ENTERA DE LO QUE VA A HACER DURANTE EL DIA?

- ☐ Ni bien me presento a la obra
- ☐ Durante la primera hora
- ☐ Durante la primera media hora
- ☐ Otro: ______________________

15. DE QUE FORMA SE LE TRASMITE LA INFORMACIÓN

- ☐ Escrita
- ☐ A través del panel
- ☐ Oral
- ☐ Otro: ______________________

CÓDIGO:

FORMATO DE ENTREVISTA PARA SUBCONTRATISTAS Y PROVEEDORES

TESISTA:
FECHA:

DE LA EMPRESA

NOMBRE: ______________________________

DIRECCIÓN: ______________________________

TELÉFONO: ______________ CORREO ELECTRÓNICO: ______________

DEL ENTREVISTADO

NOMBRE: ______________________________

TELÉFONO: ______________ CORREO ELECTRÓNICO: ______________

PREGUNTAS

¿ En qué consiste el servicio que brindan a las empresas ? (Mano de obra, materiales, diseño y mantenimiento)

____

____

____

¿Con qué frecuencia trabaja con la misma empresa?

____

____

____

¿Tiene algún convenio de trabajo con alguna empresa?

____

____

¿Ha tenido algún problema con algún cliente? Cuales? Porque? (los clientes le han causado problemas)

____

____

____

____

¿Es beneficioso para usted trabajar con la misma empresa en varios proyectos?

____

____

¿Prioriza a sus clientes? Porque?

____

____

¿Qué clase de control realiza a los servicios o productos que brinda?

____

____

¿A cuantos clientes suele atender a la vez?

____

____

¿Cuál es su capacidad de atención? (A cuantos clientes puede atender a la vez)

____

____

COMENTARIOS DEL TESISTA

____

____

____

NOTAS A LA ENTREVISTA: *(Comentarios y/o añadidos Entrevistado)*

____

____

____

CÓDIGO:

FORMATO DE ENTREVISTA PARA SUBCONTRATISTAS PEQUEÑOS

TESISTA:
FECHA:

DE LA EMPRESA

NOMBRE: ______________________________

DIRECCIÓN: ______________________________

TELÉFONO: ______________ CORREO ELECTRÓNICO: ______________

DEL ENTREVISTADO

NOMBRE: ______________________________

TELÉFONO: ______________ CORREO ELECTRÓNICO: ______________

PREGUNTAS

¿Qué aporta a la empresa ? (Mano de obra, maquinaria, materiales, diseño y mantenimiento) ¿Cuáles con los beneficios de su producto?

¿Por qué cree que la empresa debe escogerlo a usted entre otros subcontratistas?

¿Con qué frecuencia trabaja con la misma empresa?
¿Tiene algún convenio de trabajo con alguna empresa?
¿Ha tenido algún problema con algún cliente? Cuales? Porque? (los clientes le han causado problemas)
¿Es beneficioso para usted trabajar con la misma empresa en varios proyectos? ¿Por qué?
¿Prioriza a sus clientes? Porque?
¿Qué clase de control realiza a los servicios o productos que brinda? ¿Trabaja en la obra o la supervisa?
¿A cuantos clientes suele atender a la vez? ¿Cuál es su capacidad de atención? ¿Tiene algún límite?
¿Cómo escoge o contrata a su personal?
Respecto a los contratos, ¿quién los realiza? ¿siente que los contratos lo perjudican? ¿Tienen sanciones o premios?
¿Participa en la planificación?

COMENTARIOS DEL TESISTA

____
____
____

NOTAS A LA ENTREVISTA: *(Comentarios y/o añadidos Entrevistado)*

____
____
____

ANEXO 03:

Formato de Informe Final de Obra

A continuación se presenta un informe de una obra medida a manera de ejemplo del esquema utilizado en la presentación del informe final de obra, el cual era entregado a las empresas que nos abrían las puertas a su obra.

20XXXXX

INFORME FINAL: MEDICION GENERAL DE OBRA

OBRA: 20XXXXX
FECHA: Domingo, 29 de Enero de 2006 **TIEMPO MEDIDO (hrs):** 05:52
TESISTA: Pedro A. Escajadillo Iring

MARCO TEORICO:

La medición del nivel general de obra (NGO) es una de las herramientas clásicas del estudio de tiempos y movimientos, utilizado comúnmente en la ingeniería industrial. Los resultados de estas mediciones indican, en promedio, cómo está distribuido el tiempo de los trabajadores de toda la obra.

Además, considera los flujos de materiales y mano de obra que ocurren a un nivel *macro* de la obra y que, comunmente, no han sido considerados al momento de planificar y/o calcular los presupuestos (estos cálculos normalmente se realizan a nivel de actividad, es decir, a un nivel *micro* de la obra)

La metodología empleada consiste en recorridos de obra, en los cuales se observa y anota la actividad que realiza cada obrero hasta completar 400 mediciones, durante cinco días a distintas horas. Cada actividad es clasificada según su aporte a la obra, de la siguiente manera:

Trabajo Productivo (TP) Trabajo que aporta de forma directa a la producción.
Trabajo Contributorio (TC): Trabajo de apoyo, que debe ser realizado para que pueda ejecutarse el trabajo productivo. Actividad aparentemente necesaria, pero que no aporta valor.
Trabajo no contributorio (TNC): Trabajo que no genera valor y no contribuye a otra actividad; por lo tanto, se considera como actividad de pérdida.

De modo explicativo, dentro de las actividades contributorias consideramos el transporte de material y/o herramientas (T), cualquier tipo de medición (M), la limpieza (L), dar o recibir instrucciones (I) y otros contributorios (O).

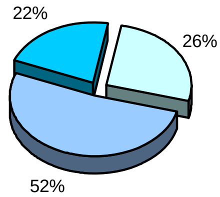
Analogamente, como trabajo no contributorio se considera los viajes sin llevar nada en las manos (V), las esperas del personal (E), ir a los servicios higiénicos (BÑ), descansar (D), rehacer un trabajo (TR), hacer trabajos sin valor (TO) y otras actividades no contributorias (OT).

PRESENTACION DE RESULTADOS:

A continuación presentamos los resultados promedio de las cinco mediciones realizadas en la obra:

	DESCRIPCION	CODIGO	% PARCIAL	% TOTAL
TP	Trabajo Productivo	P	**26.3%**	26.3%
TC	Habilitación de material	HM	7.0%	**51.9%**
	Transporte de todo	T	**22.6%**	
	Limpieza de todo	L	5.1%	
	Dar y recibir instrucciones	I	5.0%	
	Mediciones	M	5.7%	
	Otros	O	6.7%	
TNC	Viajes	V	**13.3%**	21.8%
	Esperas	E	6.1%	
	Tiempo ocioso	TO	0.1%	
	Trabajo rehecho	TR	0.5%	
	Descanso	D	0.4%	
	Baños	BÑ	0.0%	
	Otros	OT	1.6%	

En resumen,



INTERPRETACION DE RESULTADOS:

En términos prácticos, obtuvimos que de las 8 horas de jornada laboral, el obrero le dedica 2 horas a actividades productivas, 4 horas a actividades que contribuyen a las anteriores, y 2 horas a actividades que no generan valor.

COMENTARIOS:

El **trabajo productivo** oscila entre el 19,3% al 32,3%, siendo el promedio de 26,3%. El estudio realizado el año 2000 arrojó que la productividad promedio en Lima era de 28%, porcentaje cercano al obtenido en la obra. Se concluye que la obra tiene un buen potencial de mejora.
El menor trabajo productivo (19,3%) se obtuvo durante el última día de medición, el cual correspondió al encofrado del último techo. Debido a que se realizaban dos transportes en simultáneo, es decir, el transporte de encofrados al último techo a encofrar y el transporte de los encofrados que ya no son necesarios al primer piso, es justificable el valor. La actividad contributoria predominante fue el transporte con 22,8%.

Sobre el **trabajo contributorio**, podemos decir que el mayor porcentaje corresponde a la partida de transporte de herramientas y equipos. La actividad asociada directamente con ese porcentaje es el traslado de encofrados, del lugar de desencofrado hasta el lugar donde se debe encofrar. Se observa que el método de trabajo consiste en ir desencofrando en un lugar, trasladarlo y encofrarlo en el otro; tanto en encofrados de losa como en encofrados de placas.

Sobre el **trabajo no contributorio**, se observa que los porcentajes de espera y viajes son los mayores. En cuanto a los viajes, éstos van de la mano con el transporte porque el ayudante parte con las manos vacías y regresa con los materiales y/o equipos que buscaba. Normalmente, el mayor porcentaje de espera se obtiene durante los vaciados de concreto debido a los tiempos en los que se da el cambio de mixer.

RECOMENDACIONES:

Recordamos que esta herramienta representa un diagnóstico del estado de la obra y que una propuesta de mejora específica demandaría un estudio más exhaustivo de lo que ocurre en la obra; sin embargo, nos permitimos presentarle a nivel de recomendación lo siguiente:

Durante las mediciones se observó una descoordinación, en cuanto a avance se refiere, entre los encofradores de techo y los colocadores de acero de losa. Llega un momento en el que los colocadores de acero ponen las barras de acero en lugares donde no hay encofrado de losa aún. Esto provoca que, cuando llegan los encofradores a esa zona, ese acero colocado dificulte su trabajo.
El hecho es que ese percance se soluciona doblando los fierros para colocar el encofrado, luego de una pequeña discusión entre las cuadrillas involucradas.
El doblar el acero es una mala práctica y se debe evitar en lo posible. Se puede recomendar que las cuadrillas de encofrado entren a la obra una hora antes y salgan una hora antes. De ese modo, cumplen su jornada laboral y avanzan con un mayor desfase con la cuadrilla de acero.

Respecto al alto porcentaje de trabajo contributorio responde a la misma configuración de los muros, ya que no permiten el almacenaje de los encofrados cerca de los muros a encofrar. Normalmente se realiza la siguiente secuencia: desencofrado - transporte - limpieza - transporte - encofrado.
Y esta secuencia se repite a lo largo del día, por lo que se registró tantas actividades contributorias.

Finalmente, nuestro grupo de tesis le agradece la oportunidad que nos brindó al abrirnos las puertas de su obra para realizar nuestras mediciones. Si tiene algún comentario o sugerencia, le agradeceríamos escribirnos a nuestro correo electrónico **pro_tesis01@yahoo.es**

ANEXO 04:

Cuadro de Clasificación de obras por Nivel de Integración

COD.	PARTIDA	ITEMS							TIPO (PROMEDIO)	PUNTUACION						PROMEDIOS	
		1. RIESGO	2. CONTROL	3. TIPO DE CONTRATO	4. CONTINUIDAD	5. COSTOS	6. PARTIC. EN LA PLANIFICACION	7. MODO DE ELECCION		2.	3.	4.	5.	6.	7.	SUMA	PROM.
1	Carpintería	MO MAT DIS	Alto	Optimo	Alta	Bilateral	No planificacion, estrategica	Sistema Evaluacion	TIPO I	100	100	100	100	50	100	550	544
	Instalaciones eléctricas	MO	Alto	Optimo	Inicial	Bilateral	No planificacion, estrategica	Sistema Evaluacion		100	100	75	100	50	100	525	
	Instalaciones sanitarias	MO	Alto	Optimo	Alta	Bilateral	No planificacion, estrategica	Sistema Evaluacion		100	100	100	100	50	100	550	
	Movimiento de tierras	MO	Alto	Optimo	Alta	Bilateral	No planificacion, No estrategica	Sistema Evaluacion		100	100	100	100	50	100	550	
2	Acero	MO	Mediano	Optimo	Nula	Unilateral	No planificacion, estrategica	Menor costo	TIPO III	67	100	50	50	50	50	367	367
	Carpintería	MO	Mediano	Optimo	Nula	Unilateral	No planificacion, estrategica	Menor costo		67	100	50	50	50	50	367	
	Instalaciones eléctricas	MO	Mediano	Optimo	Nula	Unilateral	No planificacion, estrategica	Menor costo		67	100	50	50	50	50	367	
	Instalaciones sanitarias	MO	Mediano	Optimo	Nula	Unilateral	No planificacion, estrategica	Menor costo		67	100	50	50	50	50	367	
	Concreto	MO	Mediano	Optimo	Nula	Unilateral	No planificacion, estrategica	Menor costo		67	100	50	50	50	50	367	
3	Acero	MO	Bajo o ninguno	Formal	Alta	Bilateral	No planificacion, estrategica	Menor costo	TIPO III	33	67	100	100	50	50	400	400
	Carpintería	MO MAT	Bajo o ninguno	Formal	Alta	Bilateral	No planificacion, estrategica	Menor costo		33	67	100	100	50	50	400	
	Instalaciones eléctricas	MO	Bajo o ninguno	Formal	Alta	Bilateral	No planificacion, estrategica	Menor costo		33	67	100	100	50	50	400	
	Instalaciones sanitarias	MO	Bajo o ninguno	Formal	Alta	Bilateral	No planificacion, estrategica	Menor costo		33	67	100	100	50	50	400	
4	Carpintería	MO MAT DIS	Bajo o ninguno	Optimo	Alta	Unilateral	No planificacion, estrategica	Menor costo	TIPO III	33	100	100	50	50	50	383	355
	Acero	MO	Bajo o ninguno	Formal	Alta	Unilateral	No planificacion, estrategica	Menor costo		33	67	100	50	50	50	350	
	Instalaciones eléctricas	MO	Bajo o ninguno	Formal	Alta	Unilateral	No planificacion, estrategica	Menor costo		33	67	100	50	50	50	350	

	Instalaciones sanitarias	MO	Bajo o ninguno	Formal	Alta	Unilateral	No planificacion, estrategica	Menor costo		33	67	100	50	50	50	350	
	Instalaciones Mecánicas	MO MAT DIS MANT	Bajo o ninguno	Formal	Alta	Unilateral	No planificacion, estrategica	Menor costo		33	67	100	50	50	50	350	
	Movimiento de tierras	MO	Bajo o ninguno	Formal	Alta	Unilateral	No planificacion, estrategica	Menor costo		33	67	100	50	50	50	350	
	Concreto	MO	Bajo o ninguno	Formal	Alta	Unilateral	No planificacion, estrategica	Menor costo		33	67	100	50	50	50	350	
5	Encofrado	MO	Alto	Optimo	Alta	Unilateral	No planificacion, estrategica	Menor costo	**TIPO III**	100	100	100	50	50	50	450	**427**
	Acero	MO	Alto	Optimo	Nula	Unilateral	No planificacion, estrategica	Menor costo		100	100	50	50	50	50	400	
	Instalaciones eléctricas	MO	Mediano	Optimo	Alta	Unilateral	No planificacion, estrategica	Menor costo		67	100	100	50	50	50	417	
	Instalaciones sanitarias	MO	Mediano	Optimo	Alta	Unilateral	No planificacion, estrategica	Menor costo		67	100	100	50	50	50	417	
	Instalaciones Mecánicas	MO	Mediano	Optimo	Inicial	Unilateral	No planificacion, estrategica	Menor costo		67	100	75	50	50	50	392	
	Movimiento de tierras	MO	Mediano	Optimo	Alta	Unilateral	No planificacion, estrategica	Menor costo		67	100	100	50	50	50	417	
	Albañilería P7	MO MAT	Alto	Optimo	Alta	Unilateral	No planificacion, No estrategica	Menor costo		100	100	100	50	50	50	450	
	Tarrajeo	MO	Alto	Optimo	Alta	Unilateral	No planificacion, No estrategica	Menor costo		100	100	100	50	50	50	450	
	Mayólica	MO	Alto	Optimo	Alta	Unilateral	No planificacion, No estrategica	Menor costo		100	100	100	50	50	50	450	
6	Carpintería	MO MAT	Bajo o ninguno	Formal	Nula	Unilateral	No planificacion, estrategica	Menor costo	**TIPO III**	33	67	50	50	50	50	300	**325**
	Acero	MO	Bajo o ninguno	Formal	Alta	Unilateral	No planificacion, estrategica	Menor costo		33	67	100	50	50	50	350	
	Instalaciones eléctricas	MO	Bajo o ninguno	Formal	Alta	Unilateral	No planificacion, estrategica	Menor costo		33	67	100	50	50	50	350	
	Instalaciones sanitarias	MO	Bajo o ninguno	Formal	Alta	Unilateral	No planificacion, estrategica	Menor costo		33	67	100	50	50	50	350	
	Albañilería	MO	Bajo o ninguno	Formal	Nula	Unilateral	No planificacion, estrategica	Menor costo		33	67	50	50	50	50	300	
	Tarrajeo	MO	Bajo o ninguno	Formal	Nula	Unilateral	No planificacion, No estrategica	Menor costo		33	67	50	50	50	50	300	
7	Carpintería	MO MAT	Alto	Formal	Alta	Bilateral	No planificacion, estrategica	Menor costo	**TIPO II**	100	67	100	100	50	50	467	**467**
	Acero	MO	Alto	Formal	Alta	Bilateral	No planificacion, estrategica	Menor costo		100	67	100	100	50	50	467	
	Instalaciones eléctricas	MO	Alto	Formal	Alta	Bilateral	No planificacion, estrategica	Menor costo		100	67	100	100	50	50	467	

	Instalaciones sanitarias	MO	Alto	Formal	Alta	Bilateral	No planificacion, estrategica	Menor costo		100	67	100	100	50	50	467	
8	Albañilería P7	MO MAT	Alto	Optimo	Nula	Unilateral	No planificacion, No estrategica	Sistema Evaluacion	**TIPO II**	100	100	50	50	50	100	450	**490**
	Movimiento de tierras	MO	Alto	Optimo	Inicial	Unilateral	No planificacion, estrategica	Sistema Evaluacion		100	100	75	50	50	100	475	
	Instalaciones sanitarias	MO	Alto	Formal	Alta	Bilateral	No planificacion, estrategica	Sistema Evaluacion		100	67	100	100	50	100	517	
	Instalaciones eléctricas	MO	Alto	Formal	Alta	Bilateral	No planificacion, estrategica	Sistema Evaluacion		100	67	100	100	50	100	517	
9	Carpintería	MO MAT	Mediano	Formal	Alta	Bilateral	No planificacion, estrategica	Menor costo	**TIPO III**	67	67	100	100	50	50	434	**434**
	Instalaciones eléctricas	MO	Mediano	Formal	Alta	Bilateral	No planificacion, estrategica	Menor costo		67	67	100	100	50	50	434	
	Instalaciones sanitarias	MO	Mediano	Formal	Alta	Bilateral	No planificacion, estrategica	Menor costo		67	67	100	100	50	50	434	
10	Instalaciones eléctricas	MO	Alto	Formal	Alta	Unilateral	No planificacion, estrategica	Menor costo	**TIPO III**	100	67	100	50	50	50	417	**417**
	Instalaciones sanitarias	MO	Alto	Formal	Alta	Unilateral	No planificacion, estrategica	Menor costo		100	67	100	50	50	50	417	
	Movimiento de tierras	MO	Alto	Formal	Alta	Unilateral	No planificacion, estrategica	Menor costo		100	67	100	50	50	50	417	
	Pintura	MO	Alto	Formal	Alta	Unilateral	No planificacion, No estrategica	Menor costo		100	67	100	50	50	50	417	
11	Movimiento de tierras	MO	Bajo o Ninguno	Informal	Alta	Unilateral	No planificacion, No estrategica	Menor costo	**TIPO III**	33	33	100	50	50	50	316	**316**
12									**0%**							0	
13	Acero	MO	Mediano	Formal	Alta	Unilateral	No planificacion, estrategica	Menor costo	**TIPO III**	67	67	100	50	50	50	384	**389**
	Carpintería	MO	Mediano	Formal	Inicial	Unilateral	No planificacion, estrategica	Menor costo		67	67	75	50	50	50	359	
	Instalaciones eléctricas	MO	Mediano	Formal	Alta	Unilateral	No planificacion, estrategica	Menor costo		67	67	100	50	50	50	384	
	Movimiento de tierras	MO MAT	Mediano	Formal	Alta	Bilateral	No planificacion, estrategica	Menor costo		67	67	100	100	50	50	434	
	Instalaciones sanitarias	MO	Mediano	Formal	Alta	Unilateral	No planificacion, No estrategica	Menor costo		67	67	100	50	50	50	384	
14	Carpintería	MO MAT	Mediano	Optimo	Inicial	Bilateral	Planificacion, estrategica	Menor costo	**TIPO III**	67	100	75	100	100	50	492	**451**
	Acero	MO	Mediano	Formal	Inicial	Bilateral	Planificacion, estrategica	Menor costo		67	67	75	100	100	50	459	

	Instalaciones eléctricas	MO	Mediano	Formal	Inicial	Bilateral	Planificacion, estrategica	Menor costo		67	67	75	100	100	50	459	
	Instalaciones sanitarias	MO	Mediano	Formal	Inicial	Bilateral	Planificacion, estrategica	Menor costo		67	67	75	100	100	50	459	
	Movimiento de tierras	MO	Mediano	Formal	Nula	Bilateral	No planificacion, No estrategica	Menor costo		67	67	50	100	50	50	384	
	Carpintería	MO MAT	Mediano	Formal	Alta	Unilateral	Planificacion, estrategica	Sistema Evaluacion		67	67	100	50	100	100	484	
18	Instalaciones eléctricas	MO	Mediano	Formal	Alta	Unilateral	Planificacion, estrategica	Sistema Evaluacion	**TIPO II**	67	67	100	50	100	100	484	**484**
	Tarrajeo	MO	Mediano	Formal	Alta	Unilateral	Planificacion, no estrategica	Sistema Evaluacion		67	67	100	50	100	100	484	
	Carpintería	MO MAT	Mediano	Formal	Nula	Unilateral	No planificacion, estrategica	Menor costo		67	67	50	50	50	50	334	
	Acero	MO	Mediano	Formal	Nula	Unilateral	No planificacion, estrategica	Menor costo		67	67	50	50	50	50	334	
16	Instalaciones eléctricas	MO	Mediano	Formal	Nula	Unilateral	No planificacion, estrategica	Menor costo	**TIPO III**	67	67	50	50	50	50	334	**334**
	Instalaciones sanitarias	MO	Mediano	Formal	Nula	Unilateral	No planificacion, estrategica	Menor costo		67	67	50	50	50	50	334	
	Albañilería	MO	Mediano	Formal	Nula	Unilateral	No planificacion, No estrategica	Menor costo		67	67	50	50	50	50	334	
17									**0%**							0 0	
	Carpintería	MO	Bajo o ninguno	Formal	Nula	Unilateral	No planificacion, estrategica	Menor costo		33	67	50	50	50	50	300	
18	Acero	MO	Bajo o ninguno	Formal	Alta	Unilateral	No planificacion, estrategica	Menor costo	**TIPO III**	33	67	100	50	50	50	350	**325**
	Instalaciones eléctricas	MO	Bajo o ninguno	Formal	Inicial	Unilateral	No planificacion, estrategica	Menor costo		33	67	75	50	50	50	325	
	Instalaciones sanitarias	MO	Bajo o ninguno	Formal	Inicial	Unilateral	No planificacion, estrategica	Menor costo		33	67	75	50	50	50	325	
	Acero	MO MAT	Mediano	Optimo	Alta	Bilateral	No planificacion, estrategica	Menor costo		67	100	100	100	50	50	467	
19	Instalaciones eléctricas	MO	Mediano	Optimo	Alta	Bilateral	No planificacion, estrategica	Menor costo	**TIPO III**	67	100	100	100	50	50	467	**450**
	Instalaciones sanitarias	MO	Mediano	Optimo	Nula	Bilateral	No planificacion, estrategica	Menor costo		67	100	50	100	50	50	417	
20	Acero	MO	Bajo o ninguno	Formal	Nula	Unilateral	No planificacion, estrategica	Menor costo	**TIPO III**	33	67	50	50	50	50	300	**300**
21									**0%**							0	

	Carpintería	MO	Mediano	Formal	Nula	Unilateral	No planificacion, estrategica	Menor costo		67	67	50	50	50	50	334	
	Acero	MO	Mediano	Formal	Nula	Unilateral	No planificacion, estrategica	Menor costo		67	67	50	50	50	50	334	
22	Instalaciones eléctricas	MO	Mediano	Formal	Alta	Unilateral	No planificacion, estrategica	Menor costo	**TIPO III**	67	67	100	50	50	50	384	**354**
	Instalaciones sanitarias	MO	Mediano	Formal	Alta	Unilateral	No planificacion, estrategica	Menor costo		67	67	100	50	50	50	384	
	Albañilería P7	MO	Mediano	Formal	Nula	Unilateral	No planificacion, No estrategica	Menor costo		67	67	50	50	50	50	334	
	Instalaciones eléctricas	MO	Alto	Optimo	Nula	Unilateral	Planificacion, estrategica	Menor costo		100	100	50	50	100	50	450	
23	Instalaciones sanitarias	MO	Alto	Optimo	Nula	Unilateral	Planificacion, estrategica	Menor costo	**TIPO III**	100	100	50	50	100	50	450	**450**
	Albañilería	MO	Alto	Optimo	Nula	Unilateral	Planificacion, estrategica	Menor costo		100	100	50	50	100	50	450	
	Estructuras	MO	Alto	Optimo	Nula	Unilateral	Planificacion, estrategica	Menor costo		100	100	50	50	100	50	450	
24	Albañilería P7	MO MAT	Mediano	Formal	Nula	Bilateral	No planificacion, No estrategica	Menor costo	**TIPO III**	67	67	50	100	50	50	384	**384**
	Instalaciones sanitarias	MO MAT	Mediano	Formal	Alta	Bilateral	Planificacion, estrategica	Sistema Evaluacion		67	67	100	100	100	100	534	
25	Instalaciones eléctricas	MO	Mediano	Formal	Alta	Bilateral	Planificacion, estrategica	Sistema Evaluacion	**TIPO II**	67	67	100	100	100	100	534	**463**
	Movimiento de tierras	MO	Mediano	Formal	Nula	Bilateral	Planificacion, estrategica	Menor costo		67	67	50	100	100	50	434	
	Acero	MO MAT	Bajo o ninguno	Formal	Nula	Unilateral	Planificacion, estrategica	Menor costo		33	67	50	50	100	50	350	
	Instalaciones eléctricas	MO MAT	Mediano	Optimo	Nula	Bilateral	No planificacion, estrategica	Sistema Evaluacion		67	100	50	100	50	100	467	
26	Instalaciones sanitarias	MO MAT	Mediano	Optimo	Nula	Bilateral	No planificacion, estrategica	Sistema Evaluacion	**TIPO II**	67	100	50	100	50	100	467	**467**
	Albañilería P7	MO MAT	Mediano	Optimo	Nula	Bilateral	No planificacion, No estrategica	Sistema Evaluacion		67	100	50	100	50	100	467	
	Mayólica	MO	Mediano	Optimo	Nula	Bilateral	No planificacion, No estrategica	Sistema Evaluacion		67	100	50	100	50	100	467	

Accelerating Change

A report by the
Strategic Forum for Construction
Chaired by Sir John Egan

STRATEGIC FORUM
FOR CONSTRUCTION

Strategic Forum Membership - Chairman Sir John Egan

British Property Federation (BPF)

Commission for Architecture and the Built Environment (CABE)

Confederation of Construction Clients (CCC)

Construction Confederation (CC)

Construction Industry Council (CIC)

Construction Industry Training Board (CITB)

Construction Products Association (CPA)

Construction Research and Innovation Strategy Panel (CRISP)

Constructors Liaison Group (CLG)

Department of Trade and Industry (DTI)

Design Build Foundation/Reading Construction Forum (DBF/RCF)

Health and Safety Executive (HSE)

Housing Forum (HF)

Local Government Task Force (LGTF)

Major Contractors Group (MCG)

Movement for Innovation (M4I)

Office of Government Commerce (OGC)

Rethinking Construction (RC)

Trades Union Congress (TUC)

Secretariat

Dwight Demorais - Technical Consultant (AVPP)

Dr Rodger Evans - Department of Trade and Industry (DTI)

Contents

"It is unwise to pay too much, but it's worse to pay too little. When you pay too much, you lose a little money - that is all. When you pay too little, you sometimes lose everything, because the thing you bought was incapable of doing the thing it was bought to do. The common law of business balance prohibits paying a little and getting a lot - it can't be done. If you deal with the lowest bidder, it is well to add something for the risk you run. And if you do that, you will have enough to pay for something better."

John Ruskin 1860

Brian Wilson MP, Minister for Construction

My first acts as Minister for Construction were to announce the arrangements for the Strategic Forum for Construction and the extension of the Rethinking Construction programme for a further two years. I have kept closely in touch with the Forum's work and I very much welcome the publication of 'Accelerating Change'.

Construction is a hugely important industry. And not just because it accounts for some 8% of GDP, but because the product of the industry - the built environment - affects us all. Excellence in design can help raise productivity and business competitiveness, as well as improving our quality of life. So I welcome this report with its emphasis on creating a sustainable, customer focussed industry. We must not forget who we are building for - the end users. The industry is judged by the public on the quality of its final projects. We should therefore work together to ensure we can be proud of what we build.

I have seen that the best in the industry, especially the Rethinking Construction demonstration projects, have shown that these Rethinking Construction principles hold good in practice and deliver real tangible returns for clients, contractors, suppliers, consultants and communities.

In seeking to inculcate the principles of Rethinking Construction throughout the industry, the Strategic Forum has rightly identified the importance of client leadership. I am determined, with the help of my ministerial colleagues, to help ensure that the public sector, as the industry's largest client, plays its role in driving forward the change agenda. I want to see that the taxpayer gets value for the money we invest -in schools, hospitals, roads, and so on. Clients want construction projects that embody good whole life value and performance, excellent design and functionality, that are delivered within budget, on time and defect free.

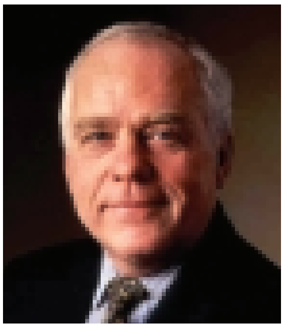
To achieve this clients need an industry that is efficient. An industry that works in a 'joined up' manner, where integrated teams move from project to project, learning as they go, driving out waste, and embracing a culture of continuous improvement.

And to do all this, as the report emphasises, the industry really must respect its people. It needs to improve its image if it is to recruit and retain the quality people it needs. I want to see concern translated into action to tackle real issues. The industry must improve its health and safety record; its poor working conditions and long hours culture; its excessive use of casual labour and neglect, in some cases, of employment rights.

To become world class the industry must invest in training, in the development of new skills, and in research and development to make the best of new materials and new technologies. Even more importantly it must change its culture and the way it does business, by working more effectively together in a partnership to meet - and exceed - its clients expectations.

I would like to pay tribute to Sir John Egan and the Strategic Forum for this report and the strategic vision it contains. The report clearly sets out what needs to be achieved. We need a vibrant, profitable, productive and competitive industry. I look forward to seeing the industry's response, and the actions being taken to 'accelerate change'.

Statement by
Sir John Egan, Chairman - Strategic Forum for Construction



In my foreword to 'Rethinking Construction', I challenged the construction industry to commit itself to change so that, by working together, a modern industry could be created. 'Accelerating Change' is evidence of the ability of the industry to come together and agree a strategic framework for action.

'Accelerating Change' is not a new initiative, it builds on and reaffirms the principles we set out in 'Rethinking Construction'. The Forum sought to tackle barriers to progress and identify ways to accelerate the rate of change. This report is the culmination of the Forum's first year's work. Independent analysis of the comments made during our consultation exercise showed an overwhelmingly positive response.

Change is already underway. I have been greatly impressed by the industry's efforts to apply 'Rethinking Construction' principles. The demonstration projects clearly show that the targets we set were realistic, and that when achieved the result brings benefit to all. I very much welcome the progress made, and congratulate those who have helped bring it about.

Some of the Forum's proposals seem controversial to some yet common sense to others. The role of the independent client advisor received considerable comment. I wish to see an end to lowest cost tendering as the main procurement tool of this industry and to replace this wasteful and unpredictable process with one where clients procure value for money against world class benchmarks and projects are delivered by integrated teams of experts involved in continuous improvement in customer satisfaction, productivity, safety and value for money. Clearly many clients will need help setting bench marks and assembling a competent integrated team to do their construction and for this I am sure independent advice will be required. Though I would prefer that the industry itself were giving the lead, the construction industry can only really lead when it is able to offer clients projects that are predictable on cost, time and quality; where the industry understands its customer's needs and can deliver products which are predictable in every way including in-use costs.

In the meantime, clients need to improve their understanding of how construction can best meet their business needs and help lead the process of creating integrated teams. Increased use of partnerships and long term framework agreements will help drive continuous improvement.

Integrated team working is key. Integrated teams deliver greater process efficiency and by working together over time can help drive out the old style adversarial culture, and provide safer projects using a qualified, trained workforce. It is self evident that teams that only construct one project learn on the job at the client's expense and hence will never be as efficient, safe, productive or profitable as those that work repeatedly on similar projects. I want to see expert teams coming together to deliver world class products, based on understanding client needs.

I also passionately believe in the importance of tackling the industry's health and safety problems. Pre-planned, well designed projects, where inherently safe processes have been chosen, which are carried out by companies known to be competent, with trained work forces, will be safe: they will also be good, predictable projects. If we are to succeed in creating a modern, world class industry, the culture of the industry must change. It must value and respect its people, learn to work in integrated teams and deliver value for clients' money.

By continuously improving its performance through the use of integrated teams, the industry will become more successful. This will in turn enable it to attract and retain the quality people it needs, which will enable it profitably to deliver products and services for its clients.

I urge you to respond to the challenge and work together with others to achieve the targets of 'Accelerating Change'

Key Measures to Accelerate Change

Vision

Our vision is for the UK construction industry to realise maximum value for all clients, end users and stakeholders and exceed their expectations through the consistent delivery of world class products and services.

Strategic Targets

By the end of 2004 20% of construction projects by value should be undertaken by integrated teams and supply chains; and, 20% of client activity by value should embrace the principles of the Clients' Charter. By the end of 2007 both these figures should rise to 50%

The Forum is determined to reverse the long-term decline in the industry's ability to attract and retain a quality workforce. To that end its members will develop and implement strategies which will enable the industry to recruit and retain 300,000 qualified people by the end of 2006, and result in a 50% increase in suitable applications to built environment higher and further education courses by 2007.

Future actions by the Forum

The Forum will

- Put in place means of measuring progress towards its targets.
- Ensure a 'Toolkit' is developed by April 2003 to help clients, and individual supply side members, assemble integrated teams, mobilise their value streams and promote effective team working skills and then produce an action plan to promote its use.
- Produce:
  - Models for payment mechanisms by April 2003
  - KPIs for payment within supply chains to help to establish and benchmark best practice by April 2003.
- Ensure a review of people initiatives is undertaken, which results in a cohesive, deliverable strategy by the middle of 2003, and which works in support of the overall vision expressed in this report.
- Develop by the end of 2002 a code of good working practices to be adopted by clients, employers, employees and trade unions.
- Press for a more concerted initiative to be developed to take forward and make the business case for IiP.
- Develop some robust examples of how changing a people culture can change a business positively.
- Develop a communication plan to spread its message throughout the SME sector; and produce a signposting booklet, pointing the way towards the most relevant and effective people initiatives, and a straightforward summary of Accelerating Change by the end of 2002.

Future actions agreed by others

The Construction Best Practice Programme will

- Develop, collate and share tools and activities specifically targeted towards SMEs to support them in all aspects of their development as part of an integrated supply team.
- The emergence of current best practice in Logistics will be collated and shared with industry through events, training and workshops to accelerate change in this important area of productivity improvement.

The Health and Safety Executive (HSE) will publish in September 2002 a wide ranging Discussion Document exploring various levers to achieve cultural change in the industry to benefit health and safety performance.

Forum recommendations.[1]

The Forum recommends that:

- Clients, who wish it, have access to independent, expert advice on all the options for meeting their business or project needs - not just those involving construction activities. Such advice should cover a range of procurement and management options, including environmental performance, operating and whole life costs. The industry, in partnership with government, should promote the value of independent advice to assist clients realise value for money.
- Clients should require the use of integrated teams and long term supply chains and actively participate in their creation.
- A list of basic competencies and a code of conduct should be made available to ensure the adequacy, consistency and independence of the service clients can expect.

[1] Many views and suggestions were expressed during the consultation phase of Accelerating Change and, overwhelmingly, the weight of opinion was in favour of the vision and strategic direction proposed and this is reflected in this final report. While many of the specific ideas do not appear in this final document, they will be taken into account, as detailed programmes are developed to implement the recommendations in this report.

- Clients should create an environment throughout all stages of the project which delivers excellence in health and safety performance.
- HSE should consider publishing details of all companies, including clients, associated with sites where fatal accidents occur.
- Existing process maps should be reviewed and signposted to encourage those who wish to actively participate in integrated teams.
- The CCC should continue to work with CBI and IOD to ensure that their members adopt the Charter's principles when commissioning construction work.
- OGC gives its work on developing simple "how to" guides high priority.
- A package of education and training (meeting the needs of SMEs and small and occasional clients) in supply team integration and collaborative working should be developed by end 2003.
- HSE include in their Approved Code of Practice reference to a system of 'gateways'. At each gateway there should be a checklist for assessing the relevant health and safety risks associated with critical stages in the planning and design process. At each stage the integrated team should be required to certify that they have - as a team - considered the health and safety risks in order to ensure that the facilities currently developed will be safe to build and safe to maintain and operate.
- Work to enable corporate competence to be readily assessed and, if necessary, validated should be carried out, and recommendations made, by September 2003.
- Project insurance products should be made available to underwrite the whole team. The construction industry, supported by its clients, should by end of 2003 present projects suitable for 'project insurance piloting' which should then be evaluated. The results should be analysed and disseminated by the Construction Best Practice Programme.
- A study, coordinated by the Specialist Engineering Contractors' Group in consultation with the industry and Government, should be carried out to examine the impact of insolvency law and practice on construction supply chains and make recommendations for change by July 2003.
- There should be widespread use of the Respect for People toolkits.
- Employers address the issue of pay and conditions in order to attract and retain the very best people in all sectors of the industry.
- The industry develops closer working relationships with schools, colleges and the Curriculum Centres offering advice and support at both design and delivery stages.
- All industry sectors identify how to demonstrate that they have a qualified workforce.
- The professional bodies jointly with the CITB and other training bodies conclude as a matter of urgency issues of professional development for graduates into management roles.
- Industry whole-heartedly adopts existing S/NVQs at levels 3,4 and 5, supported by programmes such as the CIOB's Site Management Education and Training Scheme, and the CITB's portfolio of management and supervisory training.
- CIC's forthcoming review includes a requirement to include integrated project team-working in courses achieving accreditation against the common learning outcomes.
- The industry must take responsibility for the sustainability of its products (from components to the completed structure) as well as its processes.

Vision

Our vision is for the UK construction industry to realise maximum value for all clients, end users and stakeholders and exceed their expectations through the consistent delivery of world class products and services.

In order to achieve this the UK construction industry must:

- add value for its customers, whether occasional or experienced, large or small;
- exploit the economic and social value of good design to improve both the functionality and enjoyment for its end users of the environments it creates (for example, hospitals where patients recover more quickly, schools and work places which are more productive and more enjoyable to work in, and housing which raises the spirits and enhances the sense of self worth);
- become more profitable and earn the resources it needs to invest in its future;
- enhance the built environment in a sustainable way and improve the quality of life.

Such an industry will be characterised by:

- A process that helps clients describe their needs so that as a minimum, the project delivers their requirements. (Long term strategic partnering will deliver real savings for clients and bring benefits to all in the supply chain.)
- Clients (experienced or inexperienced) procuring and specifying sustainable construction projects, products and services and a supply side that responds collaboratively to deliver these in a way that enables all in the integrated team to maximise, demonstrate and measure the added value their expertise can deliver.
- Integrated teams, created at the optimal time in the process and using an integrated IT approach, that fully release the contribution each can make and equitably share risk and reward in a non-adversarial way.
- Integrated teams made up of existing integrated supply chains, which once successfully formed are kept together and move from one project to the next taking their experience and a culture of continuous improvement with them. And, wherever possible, established integrated supply teams and supply chains are appointed.
- Strong client/customer focussed integrated teams that work proactively together to:
  - minimise risks to health and safety of all those who construct, maintain, refurbish operate and have access to the construction product;
  - drive out waste during design, planning, construction, maintenance, refurbishment and operation;
  - achieve sustainable construction by recognising that construction represents only a fraction of the cost of the building over its life span;
  - ensure a quality of design that enhances the built environment, as well as providing functionality and flexibility for the user.

> “Successful delivery of the vision will require more than integration of the supply process. It will require long-term partnerships, performance measurement, continual improvement and fair rewards for the whole supply chain.”
>
> Highways Agency

- Respect for its people, including:
  - Professional relationships and attitudes that result in behaviour based on mutual respect and where people treat others as they would wish to be treated.
  - A positive image that attracts and retains a high quality committed workforce with appropriate skills and competencies.
  - An emphasis on education, training and continuing personal and professional development.
- A culture of continuous improvement based on performance measurement.
- Investment in research and development, driven by innovation, resulting in improved performance and enhanced competitiveness and productivity.

- Consistent and continuously improving performance, and improved profitability, making it highly valued by its stakeholders.

This vision needs to be supported by an education and training process that incorporates best practice and a systematic approach to continuing professional and personal development.

Clearly the mechanisms for achieving the vision may vary, and there will be differing needs for guidance or support. However, the vision and the principles it espouses are applicable to all companies whatever their size, or position in the market.

Chapter 1

Rethinking Construction

1.1 *Rethinking Construction*[2] set out an approach whereby substantial improvements in quality and efficiency could be made. The Construction Task Force issued a challenge to the construction industry to commit itself to change, so that, working together, a modern industry could be created, ready to face the future. *Accelerating Change*, which is not a new initiative builds on the recommendations in *Rethinking Construction*, which are set out below.

Rethinking Construction - Executive Summary

- The UK construction industry at its best is excellent. Its capability to deliver the most difficult and innovative projects matches that of any other construction industry in the world.
- Nonetheless, there is deep concern that the industry as a whole is under-achieving. It has low profitability and invests too little in capital, research and development and training. Too many of the industry's clients are dissatisfied with its overall performance.
- The Task Force's ambition for construction is informed by our experience of radical change and improvement in other industries, and by our experience of delivering improvements in quality and efficiency within our own construction programmes. We are convinced that these improvements can be spread throughout the construction industry and made available to all its clients.
- We have identified five key drivers of change which need to set the agenda for the construction industry at large: committed leadership, a focus on the customer, integrated processes and teams, a quality driven agenda and commitment to people.
- Our experience tells us that ambitious targets and effective measurement of performance are essential to deliver improvement. We have proposed a series of targets for annual improvement and we would like to see more extensive use of performance data by the industry to inform its clients.
- Our targets are based on our own experience and evidence that we have obtained from projects in the UK and overseas. Our targets include annual reductions of 10% in construction cost and construction time. We also propose that defects in projects should be reduced by 20% per year.
- To achieve these targets the industry will need to make radical changes to the processes through which it delivers its projects. These processes should be explicit and transparent to the industry and its clients. The industry should create an integrated project process around the four key elements of product development, project implementation, partnering the supply chain and production of components. Sustained improvement should then be delivered through use of techniques for eliminating waste and increasing value for the customer.
- If the industry is to achieve its full potential, substantial changes in its culture and structure are also required to support improvement. The industry must provide decent and safe working conditions and improve management and supervisory skills at all levels. The industry must design projects for ease of construction making maximum use of standard components and processes.
- The industry must replace competitive tendering with long term relationships based on clear measurement of performance and sustained improvements in quality and efficiency.
- The Task Force has looked specifically at housebuilding. We believe that the main initial opportunities for improvements in housebuilding performance exist in the social housing sector for the simple reason that most social housing is commissioned by a few major clients. Corporate clients -housing associations and local authorities - can work with the house building industry to improve processes and technologies and develop quality products. We propose that a forum for improving performance in house building is established.
- The Task force has concluded that the major clients of the construction industry must give leadership by implementing projects which will demonstrate the approach that we have described. We want other clients, including those from across the public sector, to join us in sponsoring demonstration projects. We also wish to see the construction industry join us in these projects and devise its own means of making improved performance available to all its clients. Our ambition is to make a start with at least £500 million of demonstration projects.

[2] 'Rethinking Construction': The Report of the Construction Task Force, 1998 (www.rethinkingconstruction.org)

- In sum, we propose to initiate a movement for change in the construction industry, for radical improvement in the process of construction. This movement will be the means of sustaining improvement and sharing learning.
- We invite the Deputy Prime Minister to turn his Department's Best Practice Programme into a knowledge centre for construction which will give the whole industry and all of its clients access to information and learning from the demonstration projects. There is a real opportunity for the industry to develop independent and objective assessments of completed projects and of the performance of companies.
- The public sector has a vital role to play in leading development of a more sophisticated and demanding customer base for construction. The Task Force invites the Government to commit itself to leading public sector bodies towards the goal of becoming best practice clients seeking improvements in efficiency and quality through the methods that we have proposed.
- The members of the Task Force and other major clients will continue their drive for improved performance, and will focus their efforts on the demonstration projects. We ask the Government and the industry to join with us in rethinking construction.

1.2 These recommendations and the targets contained in the report have been summarised in figure 1. It has become established as the 5:4:7 mantra of Rethinking Construction.

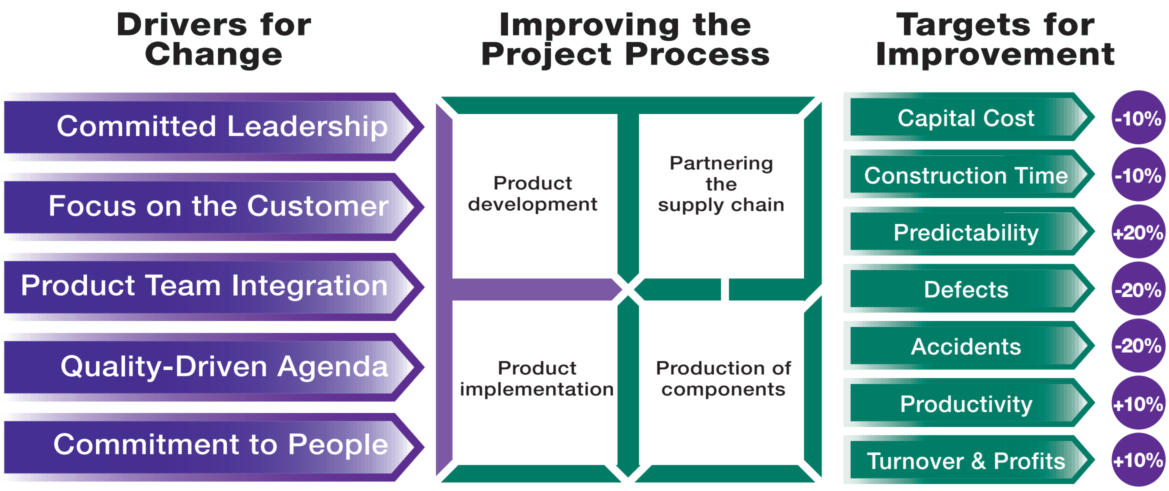


Figure 1

Chapter 2

Progress since Rethinking Construction

Rethinking Construction four years on - achievements and outputs

2.1 Rethinking Construction's objectives were, and still are, to achieve radical improvements in the design, quality, sustainability and customer satisfaction of UK construction. And for the industry to be able to recruit and retain a skilled workforce at all levels by improving its employment practices and health and safety performance. In order to achieve this the Egan Task Force proposed not only a series of targets for improvement that underpin *Rethinking Construction*, but the key drivers for change and the initial areas of process to be tackled (figure 1).

Action taken to implement Rethinking Construction

2.2 Since the publication of the report, the *Rethinking Construction* agenda has been taken forward through a dynamic partnership between government, clients and industry. **There are now more than 1,000 construction organisations actively involved in the initiative.**

2.3 Directly following the launch of the *Rethinking Construction* report the **Movement for Innovation**[3] **(M^4I)** was established by industry with Government to respond to the recommendation in the report for a movement for change. Whilst M^4I takes the lead in general construction, the **Housing Forum**[4] was established to bring together all those within the house building chain in the movement for change and innovation. Then in March 2000 the **Local Government Task Force**[5] was set up to encourage and assist local authorities to adopt the principles of *Rethinking Construction*. Following some three and a half years of activity, the decision was made in April 2002 to streamline the *Rethinking Construction* initiative by bringing together the streams under the banner of *Rethinking Construction* Ltd which acts as the main point of co-ordination and liaison, whilst maintaining their individual focus.

2.4 At the heart of the *Rethinking Construction* initiative is the demonstration projects programme. This provides the opportunity for leading edge organisations from whatever part of construction to bring forward projects that demonstrate innovation and change which can be measured and evaluated. These are either site-based projects or organisation change projects.

2.5 At the launch of *Rethinking Construction* Deputy Prime Minister, the Rt. Hon John Prescott MP and Sir John Egan challenged industry and its Clients to bring forward 50 such projects with a total value of £500 million. To date there are more than 400 of these projects in the programme, with a total value of over £6bn. 38% of these are housing projects and 62% represent the rest of the construction industry. They provide examples of off-site fabrication, standardisation, the use of new technology, sustainability, respect for people activities, partnering and supply chain integration and other areas of process improvement.

2.6 The report also exhorted industry to develop a culture of performance measurement - on the basis of if you do not measure how can you demonstrate improvement. An industry wide group developed a set of simple headline Key Performance Indicators (KPIs), based upon the 7 *Rethinking Construction* targets but with the addition of Client Satisfaction measures. In all there are 12 measures. All demonstration projects are required to measure their performance against these KPIs and to report annually. DTI collects data from industry at large, also annually, enabling a comparison to be made between all industry performance and that of the *Rethinking Construction* demonstration projects. The following data, published in May 2002,6 illustrate that comparison for the year 2001.Similar results were published in May 2000 and 2001. **Figure 2**

2.7 Taken together, these projects substantially outperform the average of the UK industry against the key indicators. More detailed results can be obtained from the *Rethinking Construction* 2002 report, from the DTI or from the Construction Best Practice Programme (CBPP) who publish them annually. Within the combined portfolio, 197 projects are entirely new build projects, and 66 are refurbishment, repairs and maintenance. The others are mixed projects. A sample of projects provides the following breakdown of projects by client type:

	Public	Private	Mixed	Social
M^4I	46%	43%	11%	-
Housing	15%	9%	4%	72%

2.8 The M^4I projects include those of a non-housing type from the LGTF, the great majority of the 46% of public projects being from this sector. Whilst

[3] Movement for Innovation: www.m4i.org.uk

[4] The Housing Forum: www.thehousingforum.org.uk

5 Local Government Task Force: www.lgtf.org.uk

M4I demonstration project performance compared to all construction for 2001[6]

Headline Key Performance Indicator	Measure	All construction	M4I	M4I Enhancement
Client Satisfaction - Product	Scoring 8/10 or better	73%	85%	+16%
Client Satisfaction - Service	Scoring 8/10 or better	65%	80%	+23%
Defects	Scoring 8/10 or better	58%	86%	+48%
Safety*	Mean accident incidence rate/100K employed	990	495	+100%
Cost Predictability - Design	On target or better	63%	81%	+29%
Cost Predictability - Construction	On target or better	50%	71%	+42%
Time Predictability - Design	On target or better	46%	81%	+76%
Time Predictability - Construction	On target or better	61%	70%	+15%
Profitability	Median profit on turnover	5.6%	7.6%	+2% percentage points
Productivity	Median value added/employee (£000)	28	34	+21%
Cost	Change compared to 1 year ago	+2%	-2%	+4%
Time	Change compared to 1 year ago	+4%	-8%	+12%

* M4I safety data are project based while All Construction data are company based

Figure 2

Government as industry sponsor and the Office of Government Commerce (OGC) have been total in their commitment to and support of *Rethinking Construction*, Government as Client needs more encouragement to become actively involved. More demonstration projects from them would be particularly welcome.

From the outset the achievements of these projects compared with the industry average have been remarkable. They have clearly demonstrated that the application of *Rethinking Construction* principles leads rapidly to:

- significant improvement in predictability of time and cost;
- enhanced quality and reduction in defects;
- marked increases in productivity and profitability;
- clear evidence that efficiently run design and construction projects are significantly safer and healthier;
- greater client satisfaction; and
- more repeat business.

2.9 Indeed, these and previous years results show that the demonstration projects are consistently exceeding the targets in *Rethinking Construction*. And more importantly, for the first time there is evidence of improvement in overall industry performance.

[6] Data source: Industry Progress report 2002 - contained in Construction Industy Key performance Indicator Pack 2002 Published by CBPP

Demonstration Projects' performance	Rethinking Construction Demonstration Projects (£6bn)	Construction Industry, as a whole (£64bn)
Profitability Rethinking Construction projects achieve **2 percentage points** more profit than the industry average	Increased profit from Demonstration Projects = **£120m**	Increased profit if one-third of industry take up = **£420m**
Construction Cost Demonstration project costs are **4.0%** lower than industry average	Reduced construction costs from Demonstration Projects = **£240m**	Reduced costs if one-third of industry take up = **£840m**
Safety Demonstration project accidents are 50% lower than industry average. Estimates put accidents costs across the industry at **8.5%** of turnover (see Rethinking Construction Report 'People - our biggest asset')	Reduced costs of accidents from Demonstration Projects = **£255m**	Reduced costs if one-third of industry take up = **£638m**

Figure 3

2.10 Based on these results, estimates have been prepared for the savings that have occurred and also the size of the savings open to the wider industry if they pursued the approaches trail-blazed by the Demonstration Projects. The table below is compiled from data collected from the *Rethinking Construction* Demonstration Projects in March 2002, and published by the Construction Best Practice Programme in the Industry Progress Report. **Figure 3 above**

2.11 Recent independent research reviewing the impact of the Demonstration Projects among participants has concluded that:

- **more than two-thirds reported improved partnering, procurement or supply change management skills in their organisation;**
- **more than half report that their organisations have made changes in eight specific areas of their business as a result; and**
- **more than two-thirds of participating individuals felt that they had been at the cutting edge of construction innovation and learned new skills.**

2.12 The lessons drawn from these demonstration projects have been used to encourage others in the industry to embark on a process of radical change. These lessons have been published in a variety of case studies, progress reports and themed reports available on the following websites: **www.m4i.org.uk** and **www.thehousingforum.org.uk**. The Construction Best Practice Programme[7] provides details of tools and training to enable these lessons to be shared. Through these sources of material the business case for change is made very clearly indeed.

Other ways in which Rethinking Construction operates

2.13 Because of the varied nature of the industry and its products, there are a number of other streams of activity within the *Rethinking Construction* initiative. These include:

The Respect for People Steering Group.

2.14 M4I published its report "A Commitment to People - Our Biggest Asset"[8] along with a set of tools that formed the basis of a trial programme. A set of KPIs to promote the image and performance of the industry in this vital area has recently been published. These trials included both demonstration projects and demonstration companies and have been concluded. A final set of toolkits will be made available to industry to help improve recruitment, retention and health and safety.

Sustainability Working Group

2.15 The launch in 2001 of the project based Environmental Performance Indicators (EPIs) has provided a key tool to drive improved sustainability in design and working practices.

[7] Construction Best Practice Programme: www.cbpp.org.uk/cbpp

[8] A Commitment to People - "Our Biggest Asset" - A report from the Movement for Innovation's working group on Respect for People, November 2000 (www.rethinkingconstruction.org/index2.htm).

Design Quality Indicators

2.16 From the outset it has been clear that quality in design and construction have to be treated as one. M^4I requested that the Construction Industry Council, supported by a DTI research grant, develop measurement tools for this crucial area; these were launched at the beginning of July 2002.

A Triple Bottom Line Case Study

Author The Construction Best Practice Programme

Beach replenishment schemes are competing increasingly with gravel extractors for a share of the UK's reserves of sand and shingle. Halcrow helped its client, a borough council, negotiate successfully with a port operator, to realise significant cost savings.

By using dredged shingle key benefits resulted from:

- One project's waste materials became another project's essential resources;
- No demand upon expensive and limited supply of licensed sand and shingle reserves;
- Port operator's requirement to dispose of dredged material at sea was reduced;
- Environmental impact of dumping gravel at sea was reduced;
- Replenishment material obtained at an estimated cost saving of £2.6 million.

The Construction Best Practice Programme

2.17 CBPP is the main dissemination arm for *Rethinking Construction* and in addition to it's programme directed primarily to SME's on today's best practice, it publishes the case studies generated by the demonstration projects on tomorrow's best practice.

Rethinking Construction in 2002

2.18 Because of the progress being made, the *Rethinking Construction* initiative was given continuing financial support by the Department of Trade and Industry for a further two years from April 2002, and is being solidly backed through the direct engagement of hundreds of companies and industry organisations, as well as other government departments. More organisations are getting involved with *Rethinking Construction* as the impact of the work gathers momentum.

2.19 Increasingly, enlightened clients are seeking to work with people who are committed to and practitioners of this agenda. At the same time government is requiring the principles of *Rethinking Construction* to guide clients' procurement practices in both central and local government.

2.20 In order to embed *Rethinking Construction* across the UK a network of 10 Regional Co-ordinators has been established to manage the Demonstration Project Programme and to work with other local organisations to promote the principles of *Rethinking Construction* to the widest possible audience. These Co-ordinators are working with the industry to develop integrated *Rethinking Construction* Centres. Centres in Wales and Northern Ireland have already been launched and others will follow over the next few months in England and Scotland. The active involvement with the Regional Development Agencies (RDAs) and of Small and Medium Sized Enterprises (SMEs) will be critical to their success.

2.21 For *Rethinking Construction* the four key objectives remain as:

1. **Proving and selling the business case for change** - Through effective monitoring and evaluation of Demonstration Projects and the collection of KPIs, continue to deliver clear evidence to the industry that continuous business improvement is achieved by following the principles and targets of *Rethinking Construction*; with particular emphasis on clients, integrated supply teams and respect for people issues.
2. **Engage clients in driving change** - Encourage clients to promote *Rethinking Construction* through involvement in demonstrations and commitment to the Clients' Charter.

3 **Involve all aspects of the industry** - Ensure that every sector of the industry is represented by active demonstration of the '*Rethinking Construction*' principles.

4 **Create a self-sustaining framework for change** - Ensure that the industry takes responsibility for developing and maintaining continuous improvement, nationally and regionally.

All this will continue to be underpinned by the programme of dissemination, support and advice provided by the Construction Best Practice Programme.

2.22 The *Rethinking Construction* initiative and movement has, we believe, already made a difference in the UK construction Industry. There is clear evidence of a mood for change, the substantial beginnings of the needed culture change, improved performance. But there is much more still to do - a need to accelerate the process of change.

Strategic Direction and Targets

Strategic Direction

3.1 The Strategic Forum identified three main drivers to accelerate change and secure a culture of continuous improvement:

- The need for client leadership
- The need for integrated teams and supply chains
- The need to address 'people issues', especially health and safety.

3.2 These embrace customer focus; supply side integration; and respect for people. These issues are strategically linked. Progress on one cannot be made at the expense of another. Clients are the starting point of the process and more must commit to procuring on the principles of best value not lowest price. The industry must respond to give impartial advice, become more customer focussed and deliver the value such clients expect.

3.3 Delivery of the vision requires collaboration between the following:

- The whole of the supply team, including clients and manufacturers;
- Government (in terms of regulation, general economic climate and as a client);
- The finance and insurance sector (recognising and acknowledging the reduced risk involved in better practice);
- Schools, further and higher education, Careers Services, national and regional funding agencies, Sector Skills Councils and the Construction Industry Training Board (CITB)[9] (to get the right sort of people with the right blend of skills and competencies);
- Research institutions;
- Professional bodies, Institutions and trade associations;
- Legal profession and contract writing bodies (preventing an adversarial approach).

3.4 This report is tantamount to a manifesto for change. The Strategic Forum looks to all who work in, or represent, these sectors to commit to the recommendations contained in this report and to participate actively in achieving the key strategic targets.

Strategic Targets

3.5 By the end of 2004 20% of construction projects by value should be undertaken by integrated teams and supply chains; and, 20% of client activity by value should embrace the principles of the Clients' Charter. By the end of 2007 both these figures should rise to 50%.

3.6 The Forum is determined to reverse the long-term decline in the industry's ability to attract and retain a quality workforce. To that end its members will develop and implement strategies which will enable the industry to recruit and retain an additional 300,000 qualified people by the end of 2006, and result in a 50% increase in suitable applications to built environment higher and further education courses by 2007.

3.7 The Forum will put in place means of measuring progress towards its targets. A significant *Rethinking Construction* benchmarking survey of the industry has been commissioned which will provide a sound basis for the measurement of change. The survey includes public and private sector clients, contractors, consultants and other suppliers totalling 1300 respondents.

[9] Construction Industry Training Board: www.citb.co.uk/citb_home.htm

Chapter 4
Accelerating Client Leadership

TARGET

20% of construction projects (by value) should be procured by clients that embrace the principles of the Clients' Charter[10] by end 2004, rising to 50% by end 2007

Those clients that adopt the Clients' Charter should achieve an annual 10% improvement in performance.

The Forum will develop a systematic basis for measurement to establish a baseline by the end of 2002.

> "The leadership that clients should give is through making their main project requirements fully transparent and creating the right environment for the supply-side to meet those requirements in the most effective way."
>
> Confederation of Construction Clients

Achieving Client Leadership

4.1 It should be self-evident that, for a successful outcome, clients should enter the construction process with a clear understanding of their 'business' needs and their environmental and social responsibilities and hence the functionality they require from the finished product. They should also understand what value means for them. Without clarity at the outset, there are likely to be changes throughout the delivery process resulting in waste, duplication, poor design and dissatisfaction for everyone involved.

4.2 Many large, repeat clients have in-house teams and processes which ensure they establish this crucial development information at the outset, before the decision to build or engage with the industry is taken. However for one-off or very occasional clients this is not usually the case. Clients, specifically small and occasional clients, should have access to relevant, simple guidance on practical steps to take when considering commissioning a construction project and how this can be made more sustainable. To help inexperienced clients draw on the knowledge of more experienced clients a generic process map has been developed and is set out in **Figure 4 and annex 2**.

Key Steps a Client must consider when faced with a Business Need

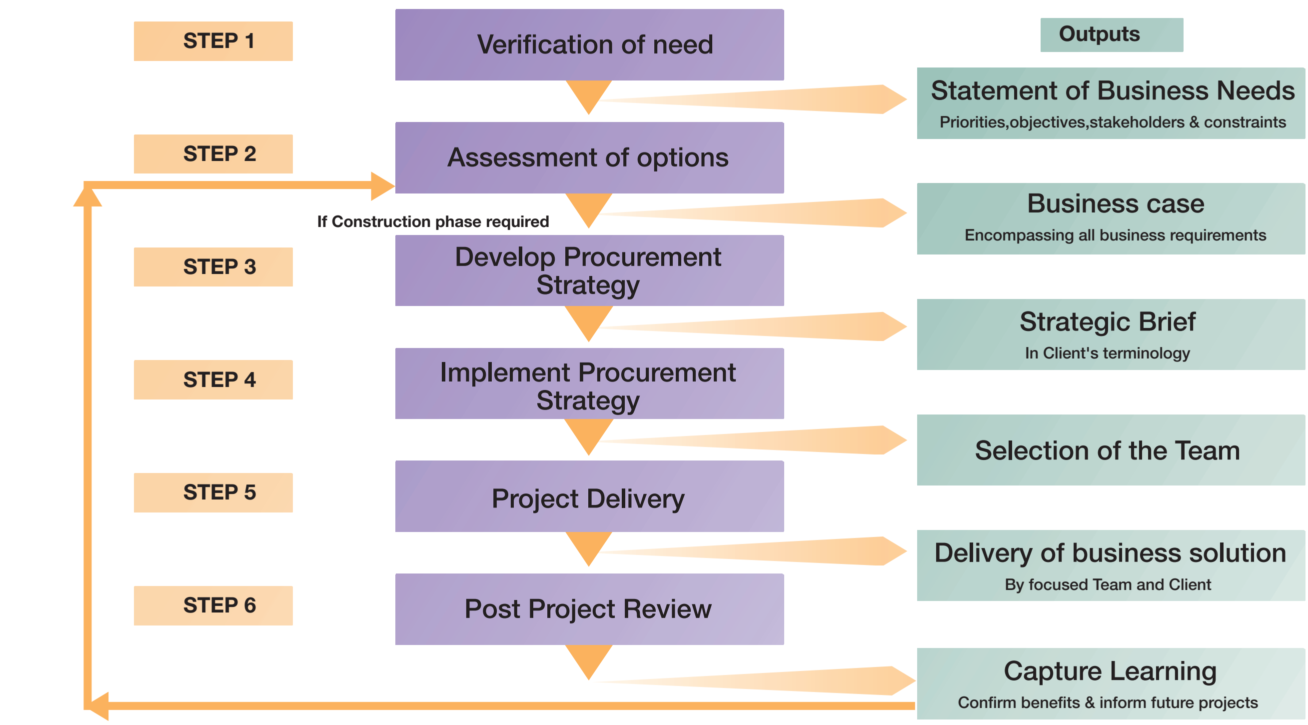


Figure 4

10 Clients' Charter : see glossary, Annex 1.

4.3 While all steps in the process are important the Strategic Forum believes that, to date, inexperienced clients do not invest sufficiently in the first two, which are vital if a successful business solution is to be achieved. This process map should be promoted on the basis that a client should seek independent advice for any of the tasks they do not feel confident in undertaking themselves. If and when required, clients in need of assistance should be able to access independent advice, which meets the principles of *Rethinking Construction*, with confidence that it is given without vested interest in the solution proposed. The Forum does not see the need for, nor does it recommend, the establishment of a new profession for the delivery of this advice. Annex 1 gives further information.

> "We've seen the success of projects using independent advisors for clients, in a client representative role focussing on non-adversarial approaches. [And] we've seen a 30% reduction in fees and a 10% reduction in prelims as a direct result of well-integrated and co-ordinated teams."
>
> Senior project manager

4.4 The Forum therefore recommends that:

- clients, who wish it, have access to independent, expert advice on all the options for meeting their business or project needs - not just those involving construction activities. Such advice should cover a range of procurement and management options, including environmental performance, operating and whole life costs. This is vital if clients are to receive better solutions which meet their needs.
- Whatever the procurement option, achieving maximum integration of the team at the optimal time should be seen as essential in order to make the best use of all available expertise, and central to the delivery of best whole life performance and maximising client value from construction. Clients should require the use of integrated teams and long term supply chains and actively participate in their creation.
- To ensure the adequacy, consistency and independence of the service clients can expect a list of basic competencies and a code of conduct should be made available. Numerous codes of practice and codes of conduct already exist in the construction sector that can help shape this work.

Health and Safety Performance

4.5 Clients should create an environment throughout all stages of the project which delivers excellence in health and safety performance. There are good business and ethical reasons to do this. Even though some clients may wrongly seek to distance themselves from health and safety during the construction process they cannot take the same attitude to the safety of the finished product, which will be used by their employees or members of the public.

4.6 Increasingly clients will be judged by their customers and by financial analysts on their ethical stance in relation to safety in the same way as is already happening for environmental performance and sustainability. Such issues have an important impact on corporate image, and on how local communities and stakeholders view them. In direct business terms,

Case Study: Confederation of Construction Clients

The Directorate of Estate Management of Cambridge University started, in 1999, to require their contractors to have 60% of their appropriate staff on site registered to CSCS or equivalent. This percentage has subsequently increased by over 10% annually so that now new contracts worth over £1million utilise over 80% of appropriate staff registered for CSCS or equivalent. The Directorate has found that particularly in recent months, contractors (and specialists) have encouraged all relevant staff, including management, to have CSCS equivalent, and will increasingly require this for access to site.

accidents on site may involve client liability and will lead to delays. Unhappy workers produce defective work.

Poor health and safety performance of the building when in use will result in the ineffective delivery of business objectives. Clients pay the price for all this avoidable waste.

4.7 Clients should deliver excellence in health and safety performance and thereby enhance their own corporate reputations by:

- Setting the requirements for healthy, safe working;
- Making health and safety of their customers, staff, and everyone they work with, or for, a business priority at the forefront of their agenda when commissioning construction;
- Using integrated supply teams to ensure the effective contribution of the entire supply chain to delivering a safe site and a safe product; and regular measurement of the extent of integration throughout the supply chain;
- Using the discipline of a "gateway" (explained in Annex 1) process to ensure they meet all their obligations to achieve a safe, efficient project. One that is more likely to be delivered on time and on budget.

4.8 The Forum recommends that, to concentrate minds further, HSE should consider publishing details of all companies, including clients, associated with sites where fatal accidents occur.

4.9 Emphasis should also be placed squarely on the training of project teams to ensure that clients, consultants, constructors and specialists are all aware of the demonstrable business, efficiency and safety benefits of integrating teams and processes. Too many organisations continue to believe that partnering and integrated procurement are experimental techniques and that the majority of their mainstream projects can still be effectively procured through traditional arrangements. Training combined with the application of that training on live projects, including the benchmarking of achievements and the sharing of lessons learned, is essential.

The Public Sector as a Client

4.10 Representing 40% of construction orders, the public sector can make a substantial difference to the widespread adoption of *Rethinking Construction* principles. It has a significant vested interest in getting best whole life value from construction if it is to demonstrate that it is spending taxpayers' money effectively and efficiently. It is important that the public sector demonstrates that it is a best practice client which consistently secures the best whole life performance that the construction industry can offer. The public sector can be helped to achieve this by:

- a financial and audit regime which supports best practice, further encouraging movement away from short-termism that places lowest initial cost ahead of whole life performance;
- removing the divide between capital and revenue expenditure in local government projects to help realise value for money as opposed to lowest price;
- linking government funding of construction projects to the application of *Rethinking Construction* principles;
- audit processes attached to such expenditure to evaluate the extent to which value and whole life performance, are used as the basis of procurement;
- providing a lead in the procurement of sustainable construction.

4.11 Some clients are concerned that the principles of integrated teams moving from project to project in order to maximise knowledge and efficiency may appear to conflict with EU and UK government procurement rules on open competition. However, the National Audit Office (NAO) addressed this issue in its report Modernising Construction[11] and concluded that provided it was undertaken in an open and transparent way with adequate measurement in place to ensure best value was in fact being delivered then this method of procurement did comply. Extensive guidance already exists to help delivery teams determine their positions within the rules and this can be found on the Office for Government Commerce's website: www.ogc.gov.uk. The guidance also emphasises whole life value. In addition, the existing process maps should be reviewed for the Forum, by the Confederation of Construction Clients (CCC), and signposted to encourage those who wish to participate actively in integrated teams. Design champions within public sector bodies will have an increasingly important role and must have an understanding of how to ensure *Rethinking Construction* is used to ensure a high quality final product.

[11] Modernising Construction, HC 87 2000-2001 ISBN 010 276 901 0 HMSO £12.00

Private Sector Clients

4.12 Private sector clients, especially those who are not experienced customers of the construction industry, should understand how their construction projects can best be carried out if they are going to fulfil their business needs. This is a key message that business organisations, and in particular the Confederation of British Industry (CBI) and the Institute of Directors (IOD), should be conveying to their members. The CCC is currently developing a 'Starter' Charter aimed at this audience. The CCC should continue to work with these business organisations to ensure that their members adopt the Charter's principles when commissioning construction work.

Client Guidance

4.13 Given the widely varying experience of clients it is clear that in developing guidance one-size does not fit all. Yet the need for simple, relevant guidance exists and must be addressed.

4.14 The Office of Government Commerce (OGC)[12] has issued a series of guidance notes for central civil government clients[13]. The OGC's 'gateway' process offers a highly relevant straightforward way to ensure that government clients are helped through the procurement process at all stages and that the principles of *Rethinking Construction* underpin this. The Forum congratulates the OGC for taking the lead in this way. The Forum urges OGC to give its work on developing simple "how to" guides high priority. The Forum will look to incorporate the gateway approach into any tools they develop.

4.15 Process maps and 'awareness raising' guidance should be developed for use by clients even before they get to the point of deciding that they need to undertake a construction project to meet their business needs. Simple awareness raising pamphlets have a role to play in getting across the message to small and occasional clients that 'there is a better way to build'. However, they should form part of the Forum's continuous long-term communications strategy that first creates awareness of effective procurement methods, and second directs clients to independent advice. In the longer term the best source of information for such prospective clients may be the independent advisers. The industry, in partnership with government, should promote the value of independent advice to assist clients to realise value for money.

4.16 The Forum welcomes the similar guidance for local authority clients that is being prepared by the Local Government Task Force to assist local authorities to maximise the value of construction procurement.

4.17 In the private sector the review currently being undertaken by the CCC of existing process maps should continue, and the resulting products made available through an easily accessible website presented to suit general client groupings, i.e. small/occasional/repeat.

4.18 Client action must also support the development of long-term integrated supply chains to increase productivity, reduce time, increase cash-flow efficiency and minimise risk. These actions need to be backed up by leadership in the construction industry to make long-term integrated supply chains the 'norm' rather than the exception.

4.19 Clients need to avail themselves of the expertise of product manufacturers and suppliers. Their input to project design can offer the potential for considerable savings through identification of standard products and detailed design solutions that are practical to implement and reliable in operation.

[12] Office of Government Commerce: www.ogc.gov.uk

[13] Office of Government Commerce Guidance Notes 1-10: http://porch.ccta.gov.uk/treasury/reports.nsf

Chapter 5

Accelerating Supply Side Integration and Integr

TARGET

20% of construction projects (by value) should be undertaken by integrated teams and supply chains by end of 2004, rising to 50% by end 2007.

The Forum will develop a systematic basis for measurement to establish a baseline by the end of 2002.

5.1 Supply side integration has a crucial part to play in increasing quality and productivity, reducing project times, increasing cash-flow efficiency and thus minimising risk, whether in terms of the reduced costs from 'getting it right first time', or added value through ensuring that people work within 'process,' not least so that health and safety risks are 'designed out' at source. Supply side integration delivers benefits during initial project delivery and by securing best value throughout subsequent use of the completed project. Moreover, supply side integration will maximise opportunities for sustainable solutions. For example, the integration of the processes of planning, design, construction installations, products and materials selection and facilities management/maintenance will result in a substantial reduction in construction costs. It is generally accepted that, at present, the number of projects delivered by integrated teams is less than 10%. This report looks forward to the time when the industry can offer a full integrated service to their clients, which will deliver predicted results in all areas. And then clients can truly be treated as customers.

OGC recommends the adoption of forms of contract that encourage team integration. These are PFI, Prime Contracting and Design and Build. From 1 June 2000 all Central Government clients were advised to limit their procurement strategies for the delivery of new works to PFI, Design and Build and Prime Contracting and from 1 June 2002 these procurement strategies should be applied to all refurbishment and maintenance contracts. Traditional non-integrated strategies will only be used where it can be clearly shown that they offer the best value for money which means in practice they will seldom be used. This policy was referred to in NAO's report Modernising Construction (HC87 Session 2000-2001: 11 January 2001) when they said (paragraph 1.13) that "all…initiatives are having an impact in improving construction performance".

Office of Government Commerce

Creating Value through Integration

5.2 Just as client action must support the development of integrated teams, and their supply chains, to achieve maximum value and optimum performance, the creation of value should be a focussed objective of integrated teams.

5.3 An integrated supply team includes the client, as well as those involved in the delivery process who are pivotal in providing solutions that will meet client requirements. Thus those involved in asset development, designing, manufacturing, assembling and constructing, proving, operating and maintaining, will have the opportunity to add maximum value by being integrated around common objectives, processes, culture/ values, and reward and risk.

5.4 Members of integrated teams should only be appointed if they have established integrated supply chains to support them, the expertise of which will be drawn upon in offering solutions to clients. Supply chains can reach from clients right through to those manufacturers who are not otherwise part of the integrated team. However, key manufacturers must be part of the integrated team.

5.5 Product manufacturers, suppliers and specialists can develop solutions that involve less site processing, increased standardisation, pre-assembly and pre-fabrication, which takes work off the site, reduces health and safety risks, and improves quality and reliability. They can also advise on availability of new products, and innovative solutions which, when linked closely to design and installation, can bring real benefits. By engaging in integrated teams their research and development expertise can be unlocked and deployed to deliver value and enhance the finished project. The early involvement of trade unions can also help realise the benefits the workforce can offer to team working. There needs to be significant investment in education and training to emphasise not just to industry new-entrants, but to existing managers through continuing personal and professional development, the importance of team working. For small and occasional clients who are uncertain how to build integrated

teams the independent client adviser would be a valuable resource.

5.6 A package of education and training (meeting the needs of SMEs and small and occasional clients) in supply team integration and collaborative working should be developed by end 2003. The integration toolkit (see below) should determine the content of the required education and training. The Forum welcomes The Design Build Foundation's offer to develop this work in liaison with the Specialist Engineering Contractors' Group, the Construction Products Association and others.

5.7 The Construction Best Practice Programme will develop, collate and share tools and activities specifically targeted towards SMEs to support them in all aspects of their development as part of an integrated supply team.

5.9 A Contractor's ability to deliver an effective service to the client can be greatly enhanced if it coordinates operations that encompass design, manufacture, delivery as well as construction.

Integration Toolkit

5.10 While integrated working is an under-utilised concept in the construction industry, clients - especially small and occasional clients - may have difficulty in understanding the benefits of, and the added value provided by, integrated working. And there are benefits for companies in the supply chain too; by acting together they are able to create a new capability, which they would not be able to do if they acted independently. Moreover integrated teams will help to develop and optimize supply chain processes that, in turn, will drive change within business organisations.

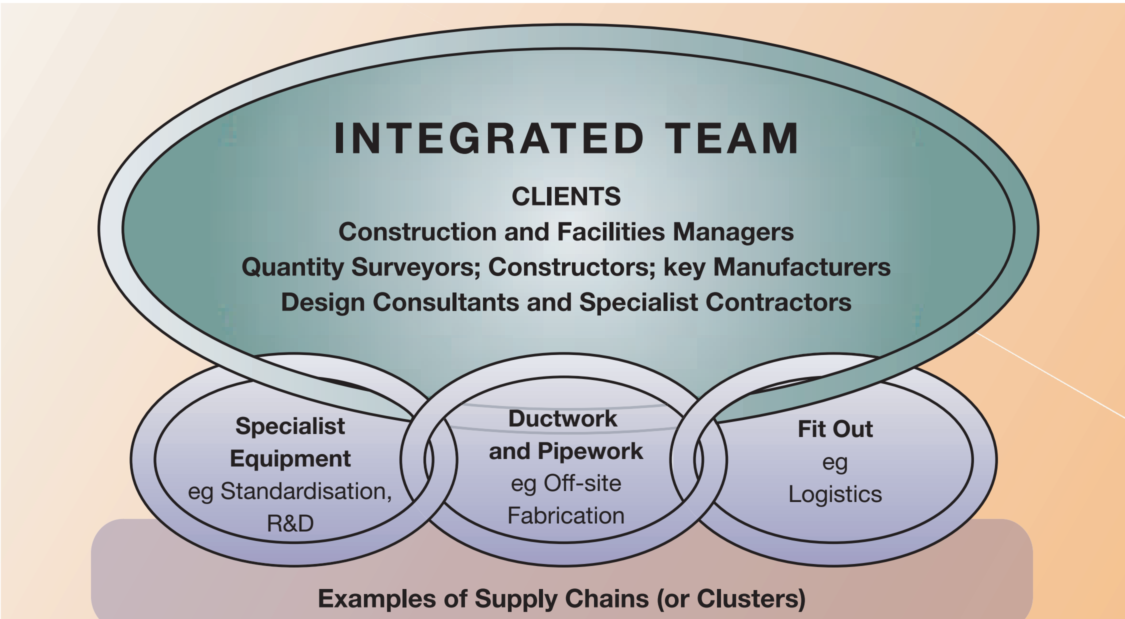


Figure 5

5.8 The major long-term benefit from integrated team working is the potential for relationship continuity. Integrated teams should be based, wherever possible, on strategic partnering. Knowledge and expertise can then be transferred more effectively from one project to the next. Whilst this is clearly of benefit to repeat clients, the benefits to one-off clients should not be ignored, as such teams will be better placed to offer them an improved service based on past experience, the ability to innovate, and through the development of a culture of continuous improvement.

5.11 The Strategic Forum will ensure that a 'Toolkit' is developed by April 2003 to help clients, and individual supply side members, assemble integrated teams, mobilise their value streams and promote effective team working skills. An action plan will be produced to promote its use. Such a toolkit will enable the full potential of the teams to be realised for the benefit of the client and should emphasise that supply team integration is relevant to small and occasional clients as well as to SMEs in the industry and can be applied to most projects (both in terms of value and type).

"Good luck! There is a role for lawyers to act as facilitators and advisors in promoting these changes. The will is there! Few realise what a sea-change there has been as a result of Latham/Egan."

Construction Lawyer

5.12 The 'toolkit' should address:

- the meaning of integrated teams and integrated supply chains;
- education and training in the value of long term integrated supply chains;
- the level of integration required;
- types of supply teams;
- the appropriate mechanisms for assembling the teams;[14]
- the benefits of project pre-planning to allow proper identification and involvement of team members;
- assembling appropriate teams that reflect the varied nature of projects;
- defining output/delivery of the team to ensure zero defects;
- identification of improvements that support greater integration;
- identification of value streams for customers, clients and suppliers;
- sustainable construction;
- measuring performance of clients and the supply teams;
- incentivisation;
- advantages of maintaining the team in place to gain the benefits of continuity for other projects;
- benefits of integrated teams (improved performance, cost saving, reduction in waste, reduced whole life costs); and
- modern payment practices.

5.13 The Toolkit should be structured to include:

- what an integrated team is;
- the principles that are required for collaborative working in an integrated team environment (i.e. leadership, processes and culture/values, trained and competent workforces, involvement of trade unions as representatives of the workforce);
- signposting from principles to real best practice examples;
- benefits and responsibilities;
- effective team working processes and team competence; and
- contract conditions that encourage team working.

"Designers must involve the contractors, specialist sub-contractors and key manufacturers as soon as possible. In order to interpret and develop a functional brief it is essential that designers (including specialist sub-contractors and key manufacturers) are able to get close to clients. Many contractors do not allow this to happen and this needs to change. Once the project is designed the advantages that can be offered by these specialists are missed."

Institution of Civil Engineers

Revisions to the Construction (Design and Management) Regulations 1994 (CDM)

5.14 The Construction (Design and Management) Regulations 1994 (CDM)[15], and accompanying Approved Code of Practice, are powerful tools to bring about accelerated progress towards integrated teams by encouraging the early appointment of the 'delivery team'.

5.15 The Health and Safety Executive (HSE)[16] will publish in September 2002 a wide ranging Discussion

14 Such mechanisms should be acceptable to both the public sector (i.e. the National Audit Office) and the private sector. The industry and its customers should have access to data for the different facilities that reflect world-class performance. The assembled teams should be committed to exceeding these levels.

15 Construction (Design and Management) Regulations 1994: www.hmso.gov.uk/si/si1994/Uksi_19943140_en_1.htm

16 Health and Safety Executive: www.hse.gov.uk

> “We agree that the initiatives covered in this section will help deliver continual improvement. In addition to examination by CSCS, there will need to be good training, good example set and acquisition of ‘life-skills’, in order for culture change to happen.”
>
> Institution for Occupational Safety and Health

Document exploring various levers to achieve cultural change in the industry to benefit health and safety performance. It will explicitly raise the role that CDM can play in securing better communication and co-operation between parties in the process. Subject to comments, the Health and Safety Commission (HSC) is then likely to publish a formal consultation document in 2003 proposing specific amendments to CDM. It should be noted, however, that vires of the Health and Safety at Work etc. Act 1974 is a legal constraint. Changes to legal requirements do not of themselves produce cultural change, but HSE wants CDM to support and encourage other non-legislative initiatives. The Forum would like to see regulations encourage the maximum integration of the team at the optimal time, and that improve the balance of responsibilities between the parties in such a way that all share legal responsibility for health and safety, and all are therefore aware of the benefits of integrated working

5.16 To help deliver this, the Forum requests HSE to include in their Approved Code of Practice reference to a system of 'gateways'. At each gateway there should be a checklist for assessing the relevant health and safety risks associated with critical stages in the planning and design process. At each stage the integrated team should be required to certify that they have - as a team - considered the health and safety risks in order to ensure that the facilities currently developed will be safe to build and safe to maintain and operate. The players within an integrated team may change over the life of a contract and each team member could only certify those aspects over which they have influence or control. Such an approach would complement and extend application of the OGC gateway reviews, see Annex 2, which are applied in the public sector.

5.17 Corporate competence is a vital adjunct to the requirement to engage competent workers. The forum recommends that work to enable corporate competence to be readily assessed and, if necessary, validated should be carried out, and recommendations made, by September 2003. All firms and their workforce within integrated teams should be qualified and competent.

Project Insurance

5.18 Integrated teams enable risk management issues to be fully addressed by the whole team in an open and transparent manner. Insurance is an aspect of risk management. Project insurance products should be made available to underwrite the whole team to facilitate integrated working. Such policies should embrace Professional Indemnity Insurance, and works contract insurance and perhaps aspects of Product Liability Insurance. Collateral insurance policies that provide cover to clients for work carried out by ongoing strategic teams already exist at manufacturer/sub-contractor level (in conjunction with a contractor licensing scheme) and should be explored further.

5.19 In spite of the current difficulties in the insurance market leading insurers are supportive of this proposal in principle. The construction industry, supported by its clients, should by end of 2003 present projects suitable for 'project insurance piloting' which should then be evaluated. The results should be analysed and disseminated by the Construction Best Practice Programme.

Case Study - BAA

Establishing integrated supply teams to develop its Terminal 5 project at Heathrow has allowed British Airports Authority to take out an all-embracing project insurance covering both professional indemnity insurance and contractor's all risks. This has significantly reduced the cost of the premiums by removing overlapping cover and introducing a non-confrontational approach which is focused around remedying the immediate event rather than trying to identify where the fault lies.

Supply Chain Management and Logistics

5.20 A considerable amount of waste is incurred in the industry as a result of poor logistics. There should be greater focus on supply chain management and logistics to facilitate integrated working and the elimination of waste. Supply chain management is the process by which one optimises the flow of goods and materials from supplier to the point of use and logistics is the process used to manage the flow of goods and materials, equipment, services and people though the supply chain.

5.21 Designers, constructors and product suppliers should examine logistics principles and how they can be applied to facilitate integration. In particular they should consider:

- the logistics of supply and delivery of goods and materials to site; and
- the tracking of goods and materials through the supply chain (manufacture to the point of use).

Both these themes have potential to deliver:

- productivity improvements;
- waste reduction;
- sustainability (energy saving);
- improvement to health and safety; and
- promotion of wider use of IT.

5.22 The emergence of current best practice in Logistics will be collated by the Construction Best Practice Programme in conjuction with the Construction Products Association and shared with industry through events, training and workshops to accelerate change in this important area of productivity improvement.

Payment Security

5.23 Payment practices should be reformed to facilitate and enhance collaborative working.

5.24 Lengthy payment periods and delays in payments severely damage construction businesses, especially small and medium sized firms. In a relationship of collective responsibility, responsible behaviour and mutual interest, as characterised by integrated teams, payment delays and retentions cease to be a significant issue. By striving to integrate the team, the industry has the opportunity to tackle a major problem that has dogged small and medium sized companies for many years. Insurance-backed, supply & fix, collateral warranties have been found to be one answer at manufacturer/sub-contractor level. With independent auditing by the underwriter the client is assured of a quality, defect-free job, whilst retentions held against the contractor are unnecessary. These should be encouraged.

5.25 The Forum will produce:

- **Models for payment mechanisms by April 2003**
- **KPIs for payment within supply chains to help to establish and benchmark best practice by April 2003.**

5.26 The forum recommends that a study, coordinated by the Specialist Engineering Contractors' Group in consultation with the industry and Government, should be carried out to examine the impact of insolvency law and practice on construction supply chains and make recommendations for change by July 2003.

5.27 These proposals do not cut across the Construction Act[17]; rather they are designed to provide the trust necessary to reinforce collaborative working.

5.28 The UK construction industry must adopt supply chain management techniques currently in use in the manufacturing industry to increase productivity, reduce time, increase cash-flow efficiency and thus minimise risk.

Case Study: MoD

Citex on its Ministry of Defence prime contract in Andover has instituted a fully transparent banking system whereby all contractors on the project are paid through a single bank account

[17] Part II of the Housing Grants, Construction and Regeneration Act 1996.

Chapter 6

Accelerating Culture Change in 'People Issues'

TARGET

The Forum is determined to reverse the long-term decline in the industry's ability to attract and retain a quality workforce. To that end its members will develop and implement strategies which will enable the industry to recruit and retain 300,000 qualified people by the end of 2006, and result in a 50% increase in suitable applications to built environment higher and further education courses by 2007.

To achieve a workforce certificated as fully trained, qualified and competent on all projects no later than 2010.

Recruitment and retention.

6.1 For many years now the construction industry has lost out to other sectors in attracting the very best people. This has been partly because of economic circumstances - boom and bust cycles have denied the industry the opportunity to train and provide long term careers for its workforce. The consequence is that we now have an aging workforce and too few people entering the industry. We need at least 300,000 over the next 5 years merely to tread water. The stable economic environment of the past 5 years has meant that we have never had a better opportunity to address the issue.

6.2 This chapter sets out some of the steps needed to turn matters round. To achieve this it must be an industry whose workforce is properly valued; able to work in healthy and safe conditions; are appropriately skilled and qualified and are developed through a systematic programme of continuing personal and professional development.

Image

6.3 How the industry attracts and retains its most valuable asset, its workforce, is critically dependent on its external image. All too often the construction industry is perceived as being a dirty, low skilled, accident prone working environment that fails to respect its people in terms of investment and development. Those with the vocational aptitude for construction industry professions and crafts are often put off by this negative image and seek careers elsewhere. This is not sustainable for the industry and it is not sustainable for the built environment of the UK. Yet this image is not entirely deserved given the large amount of work that has already been undertaken in recent years to address these issues.

6.4 A good number of initiatives have been set in train and one of the problems is that the industry is experiencing initiative overload. Too many initiatives also means that limited resources are being spread too thinly.

6.5 The Forum believes that it is now time for the industry to take a step back and carry out a full review of all the various initiatives that are currently underway and assess the real value they are adding to making the industry an attractive sector to be employed in.

6.6 The Forum will ensure this review is undertaken and results in a cohesive, deliverable strategy, by the middle of 2003 that works in support of the overall vision expressed in this report. The Strategy should reflect the key issues in this chapter and the actions that are being proposed to help accelerate change.

Respect for People

6.7 Understanding how the industry is perceived by its workforce, and placing their concerns at the heart of the industry's agenda is a prerequisite to change. Through *Rethinking Construction* ten key performance indicators have been published[18] producing construction industry performance benchmarks on, amongst other things, employee satisfaction, Investor in People (IiP), staff turnover rate, sickness, absence, pay, safety and working hours. The Strategic Forum endorses these KPI's and will promote them within the industry. They provide a mechanism for establishing how the industry responds to the call to respect its workforce and will help build up an agenda for future action.

6.8 '*Rethinking Construction*' has also produced a series of eight toolkits to help managers evaluate their performance. They encourage engagement with the workforce by collecting intelligence on their actual experience of their conditions and environment and also support better business and project performance. This directly involves the workforce in the decision making process, and will supplement the industrial relations framework already established in the industry. Widespread use of the Respect for People toolkits is recommended by the Forum.

[18] These are available from www.cbpp.org.uk or www.rethinkingconstruction.org/respect

The Respect for People Toolkits

Following two years extensive construction industry trialling the revised toolkits will be available in Oct 2002. Designed to help managers, clients, designers and project teams involved in construction projects the eight toolkits have been shown to support key approaches to development of better performance including Investors in People, The Clients Charter and Business Excellence Model and focus on the following areas:

- Workforce Satisfaction;
- Personal Working Environment;
- Safety;
- Health;
- Work in Occupied Premises;
- Training;
- Working Environment; and
- Equality & Diversity

Each toolkit comprises a simple checklist that helps evaluate appropriate items during the planning, design and construction phases of projects and supports focussed improvement action. They also direct users to first points of help and guidance on the subject under consideration.

Health and Safety

6.9 Contractors, clients and all those associated with construction can no longer simply accept the high levels of accidents and fatalities identified with this industry. Potential recruits are voting with their feet and staying away from a perceived dangerous environment. At the Construction Health and Safety summit in February 2001, the industry set itself clear targets for reducing the incidence of fatal and major accidents, ill health and working days lost as a consequence of such events. Action plans were agreed to start delivering such improvements. The Forum welcomes the Major Contractors Group's target to achieve a fully certificated workforce by the end of 2003, the Civil Engineering Contractors Association's target to achieve a workforce that is fully certified as being qualified by the end of 2007, with the remainder of the industry following no later than 2010. As has been demonstrated in other industries this will have a major impact on the number of avoidable accidents caused by a basic lack of site awareness that comes from proper training and education.

6.10 Through integration of the supply team, pre-planning can allow "designing in" for health and safety and designing out certain risks, (e.g. falls from height). Designers, whether they be architects or engineers who are designing temporary works or scaffolding, need to become more aware of the opportunities they have to minimise risks on a whole life cycle, as well as their responsibilities under the CDM Regulation and associated ACOP. The CIC, CIRIA, RIBA, RICS, ICE and other professional bodies have each produced guidance (booklets, videos, CD-Roms) to designers to enable effective implementation of the CDM Regulations in terms of designing out risks. The CIC is also committed to providing a designated construction professional who will be a health & safety 'champion' for every Higher and Further Education College offering construction courses.

6.11 Further actions that can contribute to reducing risk in this critical area include:

- using the CSCS[19] scheme to ensure that those people who work at height are competent to do so i.e. developing a specific test to evaluate their preparedness;
- maximising the opportunities to develop solutions that involve less site processing and more pre-assembly and prefabrications;
- developing transportation and materials distribution processes that reduce risk to personnel on site;
- developing an occupational health scheme for the industry. HSE is planning a pilot scheme. The pilot and work towards the wider scheme should be progressed as quickly as possible; and
- ensuring that the workforce is consulted on health and safety matters. The Major Contractors' Group is implementing a multi-step approach to workforce communication; and HSE is currently undertaking a worker safety adviser pilot. The opportunity to learn from and build on these and similar initiatives should be grasped.

Site conditions

6.12 The decisions made when projects are pre-planned will directly impact on site conditions. Construction sites are the shop window of the industry,

[19] Construction Skills Certification Scheme - See Annex 1

yet they are often perceived as being adversarial places in which to work, leading to lower productivity as well as a poor industry image. To address this issue, **the Forum will develop by the end of the year a code of good working practices to be adopted by clients, employers, employees and trade unions.**

6.13 The Considerate Constructors Scheme already helps contractors to maintain tidy, safe sites, which cause minimum disruption to the local community. The Construction Confederation's consultation kit on health and safety issues also touches on site conditions. Both of these initiatives are vehicles for promoting the proposed code of good working practice as is the *Rethinking Construction* network of demonstration projects.

Pay and Conditions

6.14 There is a clear need to offer pay and conditions which make construction an attractive industry in which to work especially at site level. Basic craft pay rates have already increased by 60% over the past six years. New apprenticeship rates have also just been agreed for England and Wales (they already existed in Scotland). However, pay rates in the industry agreements do not reflect pay rates on many sites. Further progress needs to be made to establish credible pay rates for the industry that value the existing workforce and attract new entrants. Two further issues need to be tackled to make the industry more attractive to new recruits. There is a long hours culture. Over the past five years the average working week has been 46.5 hours with over half the workforce in receipt of overtime payments. This is not healthy for the industry's employees and is costly for employers and their clients. Holiday and Pension arrangements are also relatively unattractive. Employer contributions to the industry's new stakeholder pension are relatively low and it still has to embrace all operatives in the industry. The Forum urges employers to address the issue of pay and conditions in order to attract and retain the very best people in all sectors of the industry.

Investors in People (IiP)

6.15 There is a very low take-up of IiP within construction (15% of the industry), despite its business benefits. A number of training organisations, trade associations and *Rethinking Construction* have been working to increase the take-up, but more can be done. The Forum will press for a more concerted initiative to be developed to take this forward and in make the business case for IiP. As part of the proposed 'people issues' strategy, a full action programme together with relevant signposted guidance to large companies and SMEs will be developed to increase the uptake of IiP. CITB and the Small Business Service will work in partnership to improve the impact of initiatives to encourage small companies to embrace the Investors in People standard as a route to business improvement.

Diversity

6.16 The industry needs to widen its recruitment and attract more women and more people from minority groups, which are currently very under-represented. As well as the actions endorsed under Respect of People there is a need to improve opportunities for adult learning. Women and ethnic minorities often find it more attractive to join the industry at a slightly older age. Funding for adult training and work experience needs to provide adequate support for achieving the necessary vocational qualifications.

A Qualified Workforce

6.17 It is estimated that the construction industry needs to recruit 300,000 people over the next four years to meet its needs. Getting the right people with the right skills is a priority for the industry, but so too is updating and enhancing the skills and, where applicable, management abilities of its existing staff.

6.18 If staff at all levels are to play their full part in realising value through the integration of supply chains and teams, they must be cognisant of the potential value creation opportunities and be able to identify and extract them. Delivering value for money to clients in a way that allows teams to develop efficiencies and new ways of working that can become transferable from project to project is tantamount to delivering value to the supply team.

6.19 Teachers and parents need to be made aware of the great contribution of the construction industry to improving the quality and prosperity of life and the considerable technical and creative challenges the industry offers at all levels.

Vocational Education

6.20 Tomorrow's craftsmen and women need to be getting their grounding in basic vocational skills now. Yet the national curriculum appears to work against this and steers our young people away from developing vocational skills, principally because the system is designed to set a high premium on academic success. If the industry's needs are to be addressed properly more attention and resources need to be targeted on vocational education and improving the take up of National Vocational Qualifications (NVQs) at all levels and across all sectors of the built environment.

6.21 Initiatives such as the introduction of vocational GCSEs and other similar measures proposed in the Government's Green Paper '14-19: extending opportunities, raising standards' are a step in the direction of redressing the balance. However changed structures will only work if they are accompanied by changed perceptions as to parity of esteem of academic and vocational study. Valuable work is already being undertaken through CITB's 121 Curriculum Centres working in partnership with schools and colleges. To maximise the potential offered by the new qualifications requires the industry must develop closer working relationships with schools, colleges and the Curriculum Centres offering advice and support at both design and delivery stages. This includes offering real opportunities for work-based learning supported by the industry and properly funded by the appropriate government agencies.

6.22 The promotion of role models by programmes such as the CITB Young Presenter scheme provides young people with a real insight into the wide range of career opportunities that exist within the construction industry. The industry must support CITB in its plans to increase the impact and reach of the scheme.

Graduate Entry

6.23 There has been increasing concern at the rapidly decreasing numbers applying for places on engineering and construction courses in higher education. The key issues are to ensure that:

- there are sufficient numbers of quality people entering higher education to meet the projected demand; and
- those emerging are suitably equipped with the skills, knowledge and understanding to meet the challenges of a rapidly changing industry e.g. risk management for project engineers, designing for health and safety and sustainability.

6.24 A joint initiative 'Making Connections', sponsored by DTI, CITB and CIC[20], is seeking to address both of these issues through an agreed set of actions involving government, employers, higher education institutions and professional bodies. These must be supported by changes to the working experience of our best advocate - the current workforce. Commitment from all four stakeholder communities to deliver on these actions is urgently needed if the industry is to have the graduate population and skills it requires to achieve the radical improvement in performance promoted in '*Rethinking Construction*'.

Qualifying the Workforce

6.25 An "all qualified workforce" goes far beyond simple health and safety knowledge. The industry needs to build a professional industry, improving its image and helping to change the way the workforce views itself. The quality standard being developed through expansion of, and affiliation to, the CSCS card scheme, or equivalent schemes, is an important element of the Quality Mark Scheme. It should also be in individual client assessments advocated by the Confederation of Construction Clients. All industry sectors should identify how to demonstrate that they have a qualified workforce. Achieving targets will require significant investment both in developing the necessary network of assessors and in supporting On-site Assessment and Training (OSAT) and off-site training. This will require further support from employers to develop work-based recorders and assessors, and from the Learning and Skills Council and their counterparts in Scotland and Wales, in funding adult learning.

6.26 Continuing Personal/Professional Development (CPD)[21] is also relevant to all workers in the industry including designers and managers - not least because the existing workforce also needs to keep up to speed with the changes being proposed in this report.

[20] CIC - Construction Industry Council www.cic.org.uk

[21] See Annex 1

Management and Supervisory Training

6.27 *Rethinking Construction* identified the need to improve management and supervisory skills in the drive for performance improvement. Significant shortages of supervisors and managers are anticipated and the industry remains grossly under-qualified. Long-term recruitment into industry from higher education needs to address issues of professional development for graduates into management roles, a matter for the professional bodies jointly with the CITB and other training bodies to conclude as a matter of urgency.

6.28 For a step change, large enough to raise the quality of supervision and management in the shorter term, industry needs to whole-heartedly adopt existing S/NVQs at levels 3,4 and 5, supported by programmes such as the CIOB's[22] Site Management Education and Training Scheme, and the CITB's portfolio of management and supervisory training.

Integrated Teams and Supply Chains

6.29 The creation of integrated teams and supply chains is fundamental to the success of *Rethinking Construction*. Unless there is a consistency of approach to training such teams they will not be aligned or have similar levels of competency in the necessary skills. At present the large players in the field probably provide a range of training that might cover these skills but as the smaller companies enter the supply chain it becomes less and less likely that their personnel will have been formally trained in such skills. Integrated teams need integrated training. In the same way as this document suggests that 'project insurance products should be made available to underwrite the whole team' so should appropriate training be made available to the integrated team. This would ensure that there is no disparity in the basic skill sets of the members of the integrated team (including the client).

6.30 CIC has developed Common Learning Outcomes for implementation across all university degree curricula in the built environment, with the support of 16 of the major professional institutions. These are now due for imminent review. The CIC is committed to enhance the degree of interdisciplinary working required to achieve the common learning outcomes. The Forum recommends that CIC's forthcoming review includes a requirement to include integrated project team-working in courses achieving accreditation against the common learning outcomes.

Involving SMEs

6.31 Two things have been clear in looking at people culture issues.

- First, SMEs are not as active in this area as they might be. Some are paying attention - largely because their clients are telling them to - but most do not see there is a good business case for tackling the issues, that it can create higher productivity, increase profits and significantly improve a company's image as a potential employer.
- Second, SMEs are confused and struggling to decide what to do first. There are simply too many initiatives about. Companies are confused by the conflicting initiatives and jargon and have no idea what is best for them.

The Forum has therefore identified two specific actions:

- with the help of "*Rethinking Construction*" and the Construction Best Practice Programme (CBPP) t**he Forum will develop some robust examples of how changing a people culture (whether it be for example, investment in training, diversity initiatives or good health and safety performance) can change a business positively.**
- **The Forum will then develop a communication plan to spread its message throughout the SME sector; and to help those SMEs wanting to address the issue the Strategic Forum will ensure the production of a single signposting booklet pointing the way towards the most relevant and effective people initiatives by the end of 2002.**

Enablers for change

6.32 Action in and by the construction industry to raise standards in all areas of its performance will help to achieve the vision set out in this report. Nevertheless, there are some areas where external action can help to accelerate change. Two such areas are:

The role of clients

6.33 How partners in the supply chain behave towards one another is important in developing the relationship

[22] CIOB - Chartered Institute of Building: www.ciob.org.uk

of trust that underpins successful integrated teams. Clients have an important role to play by selecting designers and contractors who honour recognized working rule agreements, who have excellent health and safety records, and who train their workforce By doing so they will help to achieve the strategic vision of excellent performance and whole life value. The developments of initiatives such as "Constructionline" and "Quality Mark"[23] provide tools to help clients select the best contractors. As the industry's single most important client, the government has a role to play in leading the way on best practice.

The Informal Construction Economy

6.34 The informal construction economy acts as a brake on achieving the vision set out in this report. In many cases, it is the most visible and unacceptable face of the construction sector to the general public. Shrinking it is an immediate priority, but there is no question that the ultimate objective should be its elimination. Its estimated value is £4.5 billion. An independent report commissioned by UCATT[24] also suggests that the number of false self-employed workers in the industry is between 300-400,000. Those companies who flout tax and employment legislation provide unfair competition for the respectable law abiding firms. They are also encouraged by those clients who seek lowest possible prices regardless of the costs. It is in this sector where there is most concern about health and safety and where "people" issues are ignored. The prize for eliminating it is an industry that can compete fairly, provide security of employment for its workers and invest in its people. DTI has released a disscusion document on employment status in relation to statutory employment rights[25] which is seeking views on the effects of extending employment rights to categories of working people who may be excludued from them.

[23] For more details on Quality Mark : www.qualitymark.org.uk

[24] Dr Mark Harvey, "Undermining Construction, The Corrosive Effect of False Self-Employment", Institute of Employment Rights, published November 2001

[25] www.dti.gov.uk/er/individual/statusdiscuss.pdf

Chapter 7

Cross-Cutting Issues

7.1 While client leadership, integrated teams and tackling 'people issues' are drivers for change, there are a number of other cross-cutting issues that can act as enablers or barriers to change. Some of these are covered below, but the list is by no means exhaustive. Nevertheless, the Forum considers that, if properly managed and developed, the issues dealt with here offer considerable opportunity to impact on the pace of change.

Sustainability

7.2 The Sustainable Construction Task Group, chaired by Sir Martin Laing, reported on the business case for sustainability in the UK property sector[26]. It rightly emphasised the importance of whole life performance in securing enduring value through productivity in use. We embrace its conclusions as being entirely consistent with the aims of Accelerating Change.

> "Sustainability is probably the most important cross-cutting issue. A construction industry that has properly embraced sustainability will be a safer industry and one that is less wasteful."
>
> UCATT

7.3 Sustainability in its broader sense of corporate social responsibility, is also a driver for change. In line with the Secretary of State for Trade and Industry's call for Trade Associations to address environmental and social impacts - alongside environmental issues - several sector organisations relating to the construction industry are developing and implementing sustainable development strategies. The strategic contribution of sustainability is integral to all aspects of this report and is therefore interwoven with the identified key issues.[27]

7.4 Sustainability did not feature as a core issue in *Rethinking Construction*, primarily because it was important at that stage to focus on the fundamental flaws in the construction procurement and delivery process. The ability to pre-plan a project through from start to finish is a prerequisite to designing in sustainability. Through pre-planning a project we can achieve the triple bottom line of sustainable development by maximising economic and social value and minimising environmental impacts.

7.5 Every link of the supply chain has a critical contribution to make towards sustainable construction and development. A poorly specified brief perpetuates waste and increased costs; without integrated teams the ability to pre-plan is lost, thereby running the risk of even greater inefficiencies and potential accidents; an undervalued and under-trained workforce make mistakes which result in financial, environmental and, all too often, human cost. The construction industry must not accept this avoidable risk and instead it must plan for sustainability. Properly qualified and competent people working as an integrated team with those who specify the project and those who can supply its needs in the most efficient way possible can better manage the risks and minimise impacts. Integration of supply process can play an important part in sustainable construction, but it also requires a step change in the culture of the industry which will be characterised by:

- clients (experienced or inexperienced) procuring and specifying sustainable construction projects, products and services; and
- a supply side that responds collaboratively to deliver these in a way that enables all in the integrated supply team to maximise the added value their expertise can deliver.

Case Study: Peabody Trust

The Beddington Zero Energy Development in south London demonstrates how to create a truly sustainable mixed-use development in a zero carbon environment with significantly reduced utility bills for all the residents. The development focuses on the specification of low embodied energy products and a reduction in the need for individual car use. It highlights how the construction industry can provide for more sustainable lifestyles.

26 Reputation, Risk & Reward - the business case for sustainability in the UK property sector': The Report of the Sustainable Construction Task Group, 2002 (http://projects.bre.co.uk/rrr/RRR.pdf)

27 Pioneering: the strategic route to sector sustainability, Sustainable development Commission

7.6 The industry must take responsibility for the sustainability of its products (from components to the completed structure) as well as its processes. Higher quality buildings will increase the value of the industry, improve its standing in society, and generally produce structures that are cheaper to run and maintain, and more pleasant to be in or use. Design quality and more sustainable processes and products should not be added onto the end; they are achievable but only if well integrated from the very beginning of the construction process. And increasingly other industries are being asked to take responsibility for products from cradle to grave, construction, too, must think about the end of life of buildings and components and the potential for recycling and reuse.

Design Quality

7.7 Investment in high quality design, by an integrated team, is crucial to the success of any construction project. It is at the outset of a project that the vast majority of value can be created through design and integration. Integrated, high quality design should always lead to a lower cost over the lifetime of a building or structure. It will also contribute to improved safety and reduced defects. To improve design standards, the industry should adopt the use of the Design Quality Indicator evaluation tool[28], being developed by the CIC, CABE and others. Design has a crucial role to play in delivering that part of the vision statement that refers to eliminating risks to health and safety of those who construct, maintain, refurbish, operate and have access to the construction product.

> “At present, the industry is still making basic mistakes regarding the construction process, and ease with which construction can achieve quality. Why is the timber window industry still manufacturing components which do not relate to brick sizes?”
>
> Architect

IT and the Internet

7.8 IT and E-business, as enablers, have already radically transformed many operations in the construction sector and there is still a vast potential for more. IT can deliver significant benefits for designers, constructors and building operators. Deriving the maximum benefit from introducing IT solutions will not, however, be easy. There is the potential to drastically reduce infrastructure cost behind the tendering side of the industry by adopting the wider use of the Internet and e-procurement specifically.

7.9 The widespread adoption of e-business and virtual prototyping requires the construction industry to transform its traditional methods of working and its business relationships. Key barriers to this transformation include organisational and cultural inertia, scale, awareness of the potential and knowledge of the benefits, skills, perceptions of cost and risk, legal issues and standards. Weighed against this, the potential benefits are:

- Efficiencies and skills development from knowledge management
- Economy and speed of construction;
- Improved business relationships;
- Product and process improvement; and
- Technology and entrepreneurship.

R&D and Innovation

7.10 Investment in research and development (R&D) is essential to underpin innovation and continuous improvement. This provides value to clients, improves profitability and the ability to compete and win in overseas markets. Sir John Fairclough's review of Government R&D Policies and Practices, *Rethinking Construction* Innovation and Research[29], endorses the view that the Strategic Forum should take the pivotal role in setting a strategic vision for the industry. This will require the support of a dedicated organisation which, when compared to the current Construction Research and Innovation Strategy Panel (CRISP)[30], will have an expanded role and resources. The new CRISP will help to identify important issues for the industry and develop research strategies to address them. The Forum feels that an immediate priority is to focus research effort on filling the industry's knowledge gap

28 Design Quality Indicator : www.dqi.org.uk

29 'Rethinking Construction, Innovation and Research': A Review of Government R&D Policies and Practices, Sir John Fairclough, 2002 (www.dti.gov.uk/construction/main.htm)

30 Construction Research and Innovation Strategy Panel: www.crisp-uk.org.uk/

in the development of integrated supply teams and mechanisms to support them to deliver of their best, such as logistics.

Planning System

7.11 The Forum welcomes the Government's recent 'Green Papers'[31] on possible reforms to the planning system. A planning system that is fair, transparent, timely and consistent will help drive out waste and costs and promote responsible development.

Small Medium Sized Enterprises

7.12 Access to relevant, clear guidance for SMEs is not always readily available. The Forum recognises the need for the expertise and enterprise of SME's to be harnessed to meet the agenda contained in this document. With this in mind, **the Forum will produce a simple summary of Accelerating Change, perhaps in the form of a wall chart, by the end of 2002.**

Housing

7.13 The Housing Forum intends to meet the particular needs of applying Accelerating Change to the housing sector. It is considering producing a bespoke document to reflect the particular circumstances and pressures facing the sector. The Housebuilders Federation plans to hold a major conference to consider Accelerating Change from the housebuilders' perspective.

Measuring Change

7.14 In building on the work of *Rethinking Construction* and delivering change to meet its objectives, it is important to be able to monitor progress against the strategic targets and deliverables set out in this report. **The Forum will put in place means of measuring progress towards its targets.**

7.15 Mechanisms and systems such as Design Quality Indicators (DQIs), Key Performance Indicators (KPIs) and Environmental Performance Indicators (EPIs) to monitor and measure progress in accelerating change already exist. In addition, a database of the recommendations and targets and deliverables derived as a result of this consultation exercise should be developed and regularly reviewed. Other useful tools to help measure change will be generated through some of the deliverables suggested in this report, such as the mechanisms that are being developed to measure progress in the use of integrated supply teams and payment practices.

[31] Planning: Delivering a Fundamental Change, Department of Transport, Local Government and the Regions, December 2001, www.planning.dtlr.gov.uk/consult/greenpap/index.htm

Annex 1

Glossary of terms and further information

Clients' Charter

The Construction Clients' Charter sets out the minimum standards they expect in construction procurement today, their aspirations for the future and a programme of steadily more demanding targets that will drive standards up in the future. By registering for the Clients' Charter which is operated for the Confederation of Construction Clients by their agents, Achilles Information Ltd, construction clients commit themselves to establish, with their suppliers, a modern business culture, through a self-imposed structured programme of change, supported by measurement against nationally accepted criteria and the exchange of best practice experience. Details of the Clients' Charter are available on www.clientsuccess@archives.com

Construction Skills Certification Scheme - CSCS

CSCS seeks to improve the construction industry's health and safety performance by identifying workers who have achieved a recognised level of competence in skills and health and safety. CSCS is a reference point for construction employers who wish to use recognised skilled workers and is a move towards a more qualified workforce.

Continuing personal and professional development

CPD (Continuing Personal/Professional Development) is defined as the holistic commitment to structured skills enhancement and personal or professional competence.

Gateways

Gateways are critical predetermined points throughout the life of a project. Before a gateway can be passed a review of all the project information and decisions to that date should be undertaken, preferably by a team of experienced people, independent of the project team. The project should not proceed to the next stage until satisfactory completion of the gateway review.

Independent Client Advice

Chapter 4 sets out the rationale for inexperienced and one-off clients who do not have the necessary skills to assess and articulate their business needs to have access to independent advice if they are to achieve successful business solutions.

Frequently asked questions about independent client advice

Who should seek independent client advice?

Clients who do not feel they have the requisite knowledge or skills to undertake all the steps required for the successful identification and delivery of a business solution.

What is the extent of the advice?

Input and help can vary throughout the life of a project. Clients should not assume that they need help for the entire process. Advice could be sought to deliver a peer review at critical stages, for clients undertaking the process themselves, or be engaged to assist in the entire process or at specific stages.

What is meant by ‘independent’ advice?

Objective advice free from any vested interest in a solution proposed as a result of the assistance given.

What is the role of people offering this advice?

They should have a non-executive role acting as a mentor to the client. They should not act as a surrogate or proxy client. They should facilitate and assist the client in fulfilling their requirements in delivering the business solution but the ultimate decisions taken remain the responsibility of the client. This is a very different service to that provided by a project manager.

Which discipline will the people offering this advice come from?

They could come from any number of disciplines. The key to the successful delivery of this role is their background experience and temperament.

Integrated Team

An integrated team includes the client and those involved in the delivery process who are pivotal in providing solutions that will meet the clients requirements. Thus those involved in asset development, designing, manufacturing, assembling and constructing, proving, operating and maintaining, will have the opportunity to add maximum value by being integrated around common objectives, processes, culture/ values, and reward & risk. An integrated team requires team members to harness the potential of their integrated supply chains.

Integrated Supply Chain

An integrated supply chain is focused on the processes associated with the reduction of the total cost of the supply chain, including, but not limited to, design, procurement, inventory management and product installation. A totally integrated supply-chain enables an end-user to more effectively and cost-efficiently manage manufacturing, inventory and transaction costs. In a true integrated supply relationship, the customer and the integrated supply partner analyse every aspect of the supply-chain process (acquisition, storage, logistics, installation, post-shipment support, information systems, etc.) and then streamline each component, eliminating redundancy of effort and cost, and improving service levels.

Logistics

Logistics is the process used to manage the flow of goods and materials, equipment, services and people though the supply chain

Supply Chain Management

Supply chain management is the process by which one optimises the flow of goods and materials from supplier to the point of use.

Sustainability

As used in 'Reputation, Risk and Reward', a report by the Sustainable Construction Task Group chaired by Sir Martin Laing: "Sustainability represents the balancing of social, environmental and economic concerns whilst recognising that decisions made today will have very real implications for future generations". Further information on 'Reputation, Risk and Reward' can be found at www.bre.co.uk and www.cbpp.org.uk.

Annex 2 : Key steps a client must consider when faced with a business need

This section sets out in more detail the key steps a Client must fulfil and if required what form the advice may take. This is an initial overview of this concept and will require further refinement over the coming months (see figure 4).

There are various models that describe the procurement process over its whole life, from the identification of a business need to the completion of a contract for goods or services, or the disposal of an asset. Different models are appropriate to different circumstances and the following outline is not intended to be prescriptive. But it reflects key stages in such models and a common theme that it is important to get the initial steps right if a project is to be successful.

Step 1 - Verification of need

1. Accurately identify and articulate the need.
2. Identify the key objectives and outcomes that the business wants to achieve.
3. Prioritise the objectives.
4. Identify the stakeholders.
5. Identify business attitude to risk.
6. Identify and prioritise significant constraints eg financial, legal, time, technology, and business change.
7. Identify internal project structure and ownership.

Outcome:

Clear statement of the business needs embracing priorities, objectives, stakeholders and constraints.

Step 2 - Assessment of options

1. Develop and appraise all the options.
2. Research the learning from past experience (both your own and others experience).
3. Review the preferred option with the business stakeholders and confirm that it will deliver the business needs and objectives, is realistic and meets the requirements in relation to risk and constraints.

Outcome:

A robust business case that meets all the business requirements.

If the preferred option requires a construction phase:

Step 3 - Develop Procurement strategy

1. Research the options for procuring the project and determine the strategy.
2. Research the learning from past experience (both your own and others experience).
3. Confirm project performance criteria.
4. Review business plan, financial requirements and risks, and controls.
5. Confirm stakeholder commitment.
6. Confirm that the procurement approach will support and encourage good client/supplier relations.

Outcome:

Strategic Brief articulating, in the client's terminology, the project objectives, needs, priorities, constraints, budget, programme, decision making framework, measures of success and method of selection for the most appropriate delivery of the required business solution.

Step 4 - Implement Procurement strategy

Implement the procurement strategy and select the team best placed to delivery the required business solution. (Throughout this process the Client, by his actions, will set the tone by which he expects the project to be delivered.)

Step 5 - Project delivery

1. Validate and improve the Strategic Brief.
2. Brief the team regarding all aspects of the project (Needs, objectives, risks, constraints and stakeholders.)
3. Implement appropriate and agreed performance measurements.
4. Ensure new members brought into the team are inducted with regard to the business needs, objectives and method of delivery.
5. Make appropriate and timely decisions always referring back to and validating the project objectives.
6. Advise the business on steps to be taken for regarding the implementation and operation of the new asset.

Outcome:

Project team fully focused on delivering the most appropriate solution to meet the client's business needs within the agreed parameters and a business prepared to embrace the new asset within its operations.

Step 6 - Post Project Review

1. Undertake assessment of new asset
2. Measure final delivery performance against the targets set.
3. Review project history.

Outcome:

Capture project learning to confirm benefits and to inform future projects.

Annex 3

Publications and useful websites

Publications

'Rethinking Construction': The Report of the Construction Task Force, 1998

Reputation, Risk & Reward - the business case for sustainability in the UK property sector': The Report of the Sustainable Construction Task Group, 2002.

'*Rethinking Construction*, Innovation and Research': A Review of Government R&D Policies and Practices, Sir John Fairclough, 2002

"A commitment to people - our Biggest Asset" - A report from the Movement for Innovation's working group on Respect for People, November 2000.

Building a better quality of life: A strategy for more sustainable construction, DETR, April 2000

Achieving Sustainability in Construction Procurement, Sustainability Action Group of the

Government Construction Clients' Panel (GCCP), June 2000

Planning: Delivering a Fundamental Change, Department of Transport, Local Government and the Regions, December 2001

Construction (Design and Management) Regulations 1994:
www.hmso.gov.uk/si/si1994/Uksi_19943140_en_1.htm

OGC Publications

No.1: Essential Requirements for Construction Procurement Guide

No.2: Value for Money in Construction Procurement

No.3: Appointment of Consultants and Contractors

No.4: Teamworking, Partnering and Incentives

No.5: Procurement Strategies

No.6: Financial Aspects of Projects

No.7: Whole Life Costs

No.8: Project Evaluation and Feedback

No.9: Benchmarking

No 10: Achieving Excellence through Health and Safety

Useful Websites

Commission for Architecture and the Built Environment: www.cabe.org.uk

Confederation of Construction Clients: www.clientsuccess.org.uk

Construction Best Practice Programme: www.cbpp.org.uk/cbpp/

Construction Industry Council: www.cic.org.uk

Construction Industry Training Board: www.citb.org.uk/citb_home.htm

Construction Research and Innovation Strategy Panel: www.crisp-uk.org.uk/

Department of Trade and Industry's Construction Pages: www.dti.gov.uk/construction/

Design Quality Indicators www.dqi.org.uk

Health and Safety Executive: www.hse.gov.uk

Her Majesty's Stationary Office: www.hmso.gov.uk

Housing Forum: www.thehousingforum.org.uk

Local Government Task Force: www.lgtf.org.uk

Movement for Innovation: www.m4i.org.uk

Office of Government Commerce: www.ogc.gov.uk

Rethinking Construction: www.rethinkingconstruction.org

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CIFE CENTER FOR INTEGRATED FACILITY ENGINEERING

APPLICATION OF THE NEW PRODUCTION PHILOSOPHY TO CONSTRUCTION

By

Lauri Koskela

CIFE Technical Report #72

September, 1992

STANFORD UNIVERSITY

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Summary: **TECHNICAL REPORT #72**

Title: **Application of the New Production Philosophy to Construction**

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1. **Abstract:** The background and development of the new production philosophy are presented. The conceptual basis of the traditional and the new production philosophies, as applied in manufacturing, are examined. The traditional conceptual basis of construction is criticized, and an initial new interpretation of construction is given based on the new philosophy. Finally, the challenges of implementing the new production philosophy in construction are considered.

2. **Subject:** The term "new production philosophy" refers to an evolving set of methodologies, techniques and tools, the genesis of which was in the Japanese JIT and TQC efforts in car manufacturing. Several alternative names are presently used to refer to this philosophy: lean production, JIT/TQC, world class manufacturing, time based competition. In manufacturing, great gains in performance have been realized by this new production philosophy. With the exception of quality methodologies, this new philosophy is little known in construction.

3. **Objectives/Benefits:** The goal of this report is to assess whether or not the new production philosophy has implications for construction.

4. **Methodology**: The study consisted mainly of a literature review and a conceptual analysis and synthesis. In the last stage of the study, four engineering or construction companies were visited to ascertain the present level of implementation of the new philosophy.

5. **Results**: Construction should adopt the new production philosophy. In manufacturing, the new production philosophy improves competitiveness by identifying and eliminating waste (non value-adding) activities. Traditionally, construction is viewed and modeled only as a series of conversion (value-adding) activities. For example, waste activities such as waiting, storing inventory, moving material, and inspection are not generally modeled by Critical Path Models (CPM) or other control tools. Construction has traditionally tried to improve competitiveness by making conversions incrementally more efficient. But judging from the manufacturing experience, construction could realize dramatic improvements simply by identifying and eliminating non conversion (non value-adding) activities. In other words, actual construction should be viewed as flow processes (consisting of both waste and conversion activities), not just conversion processes. As demonstrated previously by the manufacturing industry's experience, adoption of the new production philosophy

will be a fundamental paradigm shift for the construction industry. The implications of this for design is that the process of construction must be developed in conjunction with the design itself.

An initial set of design and improvement principles for flow processes is presented that can serve as an implementation guideline.

Major development efforts in construction, like industrialization, computer integrated construction and construction automation have to be redefined to acknowledge the need to balance flow improvement and conversion improvement.

The conceptual foundation of construction management and engineering, being based on the concept of conversion only, is obsolete. Formalization of the scientific foundations of construction management and engineering should be a primary long term task for research.

6. **Research status**: This exploratory study raises a series of research questions. Some of them are currently addressed in other ongoing CIFE projects. For example, the relation between process improvement and technical integration is assessed in the study on integration's impact on plant quality. Other questions will be addressed in future CIFE projects.

The author will continue this line of research at the Technical Research Centre of Finland, focusing on problems of implementation.

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EXECUTIVE SUMMARY

1. In manufacturing, great gains in performance have been realized by a new production philosophy. In construction, this new philosophy is little known.

2. The conventional thinking views production as conversion processes. The new philosophy views production as consisting of both conversions and flows. Only conversions add value. This has fundamental implications for design, control and improvement of production processes.

3. The improvement of flow activities should primarily be focused on reducing or eliminating them, whereas conversion activities have to be made more efficient. An initial set of design and improvement principles for flow processes has evolved.

4. In construction, conceptualization of production is based on the conversion process model, as formerly in manufacturing.

5. According to the new view, a construction project consists of three basic flows (design process, material process and work process) and supporting flows. For most participating organizations, these processes repeat from project to project with moderate variations.

6. Traditional managerial concepts, based on the conversion conceptualization, have ignored and often deteriorated flows in construction.

7. As a consequence of traditional managerial concepts, construction is characterized by a high share of non value-adding activities and resultant low productivity.

8. The peculiarities of construction (one-of-a-kind projects, site production, temporary organization) often prevent the attainment of flows as efficient as those in stationary manufacturing. However, the general principles for flow design, control and improvement apply: construction flows can be improved, in spite of these peculiarities.

9. Due to deficient conceptualization, such development efforts as industrialization and computer integrated construction have often been misdirected. The resultant neglect of process improvement has become a barrier for progress.

10. The concept of process improvement provides a framework, which can - and should - be immediately applied in all construction industry organizations.

11. Measures, which directly pinpoint improvement potential (waste or value) and facilitate targeting and monitoring of improvement, are crucial for implementation of process improvement.

12. The conceptual basis of construction management and engineering is obsolete. Formalization of the scientific foundations of construction management and engineering should be a primary long term task for research.

ACKNOWLEDGEMENTS

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The ideas of the report, in their various stages, were commented upon by several faculty members and students in the Department of Civil Engineering and the Center for Integrated Facility Engineering at Stanford University. Valuable feedback was also given by construction faculty members of UC Berkeley.

1 Introduction

The problems of construction are well-known. Construction productivity lags that of manufacturing. Occupational safety is notoriously worse than in other industries. Due to inferior working conditions, there are work force shortages in many countries' construction sector. The quality of construction is considered to be insufficient.

A number of solutions or visions have been offered to relieve the chronic problems in construction. Industrialization (i.e. prefabrication and modularization) has for a long time been viewed as one direction of progress. Currently, computer integrated construction is seen as an important way to reduce fragmentation in construction, which is considered to be a major cause of existing problems. The vision of robotized and automated construction, closely associated with computer integrated construction, is another solution promoted by researchers.

Manufacturing has been a reference point and a source of innovations in construction for many decades. For example, the idea of industrialization comes directly from manufacturing. Computer integration and automation also have their origin in manufacturing, where their implementation is well ahead compared to construction.

Now, there is another development trend in manufacturing, the impact of which appears to be much greater than that of information and automation technology. This trend, which is based on a new production philosophy, rather than on new technology, stresses the importance of basic theories and principles related to production processes. However, because it has been developed by practitioners in a process of trial and error, the nature of this approach as a philosophy escaped the attention of both professional and academic circles until the end of 1980's.

In construction, there has been rather little interest in this new production philosophy. The goal of this report is to assess whether or not the new production philosophy has implications for construction.

The study on which this report is based consisted mainly of a literature review and a conceptual analysis and synthesis. In the last stage of the study, four companies were visited to ascertain the present level of implementation of the new approach. Findings from companies are presented as anecdotal evidence in support of argumentation.

The structure of the report is as follows. In Chapter 2, the background and development of the new production philosophy are presented. In Chapter 3, the conceptual basis of the traditional and the new production philosophies, as applied in manufacturing, are examined. Chapter 4 analyzes and critiques the traditional conceptual basis of construction. An interpretation of construction based on the new philosophy is given in Chapter 5. Next, the implementation of the new production philosophy in construction is considered in Chapter 6. Finally, Chapter 7 contains a short summary of the report.

2 New production philosophy: origin, development, and main ideas

2.1 Origins and diffusion

The ideas of the new production philosophy first originated in Japan in the 1950's. The most prominent application was the Toyota production system. The basic idea in the Toyota production system is the elimination of inventories and other waste through small lot production, reduced set-up times, semiautonomous machines, co-operation with suppliers, and other techniques (Monden 1983, Ohno 1988, Shingo 1984, Shingo 1988).

Simultaneously, quality issues were attended to by Japanese industry under the guidance of American consultants like Deming, Juran and Feigenbaum. Quality philosophy evolved from a statistical method of quality assurance to a wider approach, including quality circles and other tools for company-wide development.

These ideas were developed and refined by industrial engineers in a long process of trial and error; establishment of theoretical background and wider presentation of the approach was not seen as necessary. Consequently, up to the beginning of the 1980's, information and understanding of the new approach in the West was limited. However, the ideas diffused to Europe and America starting in about 1975, especially in the automobile industry.

During the 1980's, a wave of books were published which analyzed and explained the approach in more detail (Deming 1982, Schonberger 1982, Schonberger 1986, Hayes & al. 1988, O'Grady 1988, Garvin 1988, Berangér 1987, Edosomwan 1990).

In the beginning of the 1990's, the new production philosophy, which is known by several different names (world class manufacturing, lean production, new production system) is the emerging mainstream approach. It is practiced, at least partially, by major manufacturing companies in America and Europe. The new approach has also diffused to new fields, like customized production (Ashton & Cook 1989), services, administration (Harrington 1991), and product development.

In the meantime, the new production philosophy has been undergoing further development, primarily in Japan. New approaches and tools have been established to augment the philosophy, such as Quality Function Deployment (QFD) (Akao 1990), Taguchi-method, design for manufacture, etc.

In Japan, the spearhead organization for the new approach is the New Production System (NPS) Research Association, formed in 1982 for refining and implementing the new production system in member companies (Shinohara 1988).

2.2 Main ideas and techniques

2.2.1 Overview

Several factors make it difficult to present a coherent overview of the ideas and techniques of the new production philosophy. The field is young[1] and in constant evolution. New

[1] The first scholarly paper in English was published in 1977 (Golhar & Stamm 1991).

concepts emerge and the content of old concepts change. The same concept is used to refer to a phenomenon on several levels of abstraction. It is not clear where to place the boundaries between related concepts.

We have chosen to base this overview on two historically important "root" terms, Just In Time (JIT) and Total Quality Control (TQC), which are outlined briefly below. Next we present related newer concepts, which are primarily outgrowths of JIT and TQC. These outgrowths show that the field of application of the original ideas has extended far beyond the production sphere.

2.2.2 Just In Time (JIT)

The starting point of the new production philosophy was in industrial engineering oriented developments initiated by Ohno and Shingo at Toyota car factories in the 1950's. The driving idea in the approach was reduction or elimination of inventories (work in progress). This, in turn, led to other techniques that were forced responses to coping with less inventory: lot size reduction, layout reconfiguration, supplier co-operation, and set-up time reduction. The pull type production control method, where production is initiated by actual demand rather than by plans based on forecasts, was introduced.

The concept of waste is one cornerstone of JIT. The following wastes were recognized by Shingo (1984): overproduction, waiting, transporting, too much machining (overprocessing), inventories, moving, making defective parts and products. Elimination of waste through continuous improvement of operations, equipment and processes is another cornerstone of JIT[2].

2.2.3 Total Quality Control (TQC)

The starting point of the quality movement was the inspection of raw materials and products using statistical methods. The quality movement in Japan has evolved from mere inspection of products to total quality control. The term total refers to three extensions (Shingo 1988): (1) expanding quality control from production to all departments, (2) expanding quality control from workers to management, and (3) expanding the notion of quality to cover all operations in the company.

The quality methodologies have developed in correspondence with the evolution of the concept of quality. The focus has changed from an inspection orientation (sampling theory), through process control (statistical process control and the seven tools[3]), to continuous process improvement (the new seven tools[4]), and presently to designing quality into the product and process (Quality Function Deployment).

There has always been friction between the JIT camp and the quality camp. Representatives of the JIT camp tend to stress process improvement (Harmon 1992) and error checking at the source (Shingo 1986) rather than statistical control and quality programs.

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[2] For a short discussion of JIT, see (Walleigh 1986). For opposing views, see (Zipkin 1991).

[3] Pareto-diagram, cause-and-effect diagram, histogram, control chart, scatter diagram, graph and checksheet.

[4] Relations diagram, affinity diagram, tree diagram, matrix diagram, matrix data-analysis diagram, process decision program chart, arrow diagram.

2.2.4 Related concepts

Many new concepts have surfaced from JIT and TQC efforts. These have been rapidly elaborated and extended, starting a life of their own. Several of these concepts are described below.

Total Productive Maintenance (TPM)

Total productive maintenance refers to autonomous maintenance of production machinery by small groups of multi-skilled operators (Nakajima 1988). TPM strives to maximize production output by maintaining ideal operating conditions. Nakajima states that without TPM, the Toyota production system could not function.

Employee involvement

There are several reasons for employee involvement (for a good, concise discussion, see Walton 1985). Rapid response to problems requires empowerment of workers. Continuous improvement is heavily dependent on day-to-day observation and motivation of the work force, hence the idea of quality circles (Lillrank & Kano 1989). In order to avoid waste associated with division of labor, multi-skilled and/or self-directed teams have been established for product/project/customer based production.

Continuous improvement

Continuous improvement, associated with JIT and TQC, has emerged as a theme in itself especially after the book by Imai (1986). A key idea is to maintain and improve the working standards through small, gradual improvements. The inherent wastes (as characterized in section 2.2.2) in the process are natural targets for continuous improvement. The term “learning organization” refers partly to the capability of maintaining continuous improvement (Senge 1990).

Benchmarking

Benchmarking refers to comparing one’s current performance against the world leader in any particular area (Camp 1989, Compton 1992). In essence, it means finding and implementing the best practices in the world. Benchmarking is essentially a goal-setting procedure, which tries to break down complacency and NIH-attitudes (not invented here). It focuses on business processes, rather than the technologies used in them. The procedure of benchmarking was formalized in the 1980’s based on work done at Xerox (Camp 1989). Japanese companies informally applied benchmarking earlier.

Time based competition

The book by Stalk and Hout (1990) popularized this term. Time based competition refers to compressing time throughout the organization for competitive benefit. Essentially, this is a generalization of the JIT philosophy, well-known to the JIT pioneers. Ohno states that shortening lead time creates benefits such as a decrease in the work not related to processing, a decrease in the inventory, and ease of problem identification (Robinson 1991). Time based competition has become popular, especially in administrative and information work where the JIT concepts sound unfamiliar.

Concurrent engineering

Concurrent (or simultaneous) engineering deals primarily with the product design phase. As far as is known, it did not originate directly from JIT or TQC, even though it is based on similar ideas. The term refers to an improved design process characterized by rigorous upfront requirements analysis, incorporating the constraints of subsequent phases into the conceptual phase, and tightening of change control towards the end of the design process. In comparison to the traditional sequential design process, iteration cycles are transferred to the initial phases through teamwork. Compression of the design time, increase of the number of iterations, and reduction of the number of change orders are three major objectives of concurrent engineering.

Various tools for concurrent engineering have been developed, such as the principles and systems used in Design for Assembly and Design for Manufacturability.

Value based strategy (or management)

Value based strategy refers to “conceptualized and clearly articulated value as the basis for competing” (Carothers & Adams 1991). Firms driven by value based strategies are customer-oriented, in contrast to competitor-oriented firms. Continuous improvement to increase customer value is one essential characteristic of value based management.

Visual management

Visual management is an orientation towards visual control in production, quality and workplace organization (Greif 1991). The goal is to render the standard to be applied and a deviation from it immediately recognizable by anybody. This is one of the original JIT ideas, which has been systematically applied only recently in the West .

Re-engineering

This term refers to the radical reconfiguration of processes and tasks, especially with respect to implementation of information technology (for example Hammer 1990, Davenport & Short 1990, Rockart & Short 1989). According to Hammer, recognizing and breaking away from outdated rules and fundamental assumptions is the key issue in re-engineering.

Lean production, world class manufacturing

Rather than defining a specific set of methods, these terms are loosely used to refer to an intensive use of the ideas of the new production philosophy.

2.3 Conceptual evolution

The conception of the new production philosophy has evolved through three stages (Plenert 1990). It has been understood primarily as

- a set of tools (like kanban and quality circles)
- a manufacturing method (like JIT)
- a general management philosophy (referred to as lean production, world class manufacturing, JIT/TQC, time based competition, etc.).

This progression is due to the characteristics of the new approach as an engineering-based innovation in contrast to a science-based innovation. The practical application of the new philosophy began and was diffused without any scientific, formalized basis: factory visits, case descriptions and consultants have been the means of technology transfer.

The conception of the new production philosophy as a general management philosophy was first promoted by Deming (1982), Schonberger (1990), the NPS Research Association (Shinohara 1988) and Plossl (1991). Each has formulated a set of implementation principles.

A number of definitions of the new production philosophy are exhibited in Table 1. Even a superficial analysis shows that they differ widely. The theoretical and conceptual understanding of the new production approach is still limited. In spite of initial efforts to raise the abstraction level of the definition (as evident with Plossl, Table 1), there is as yet no unified, coherent and consistent theory. Rather, the new approach could be characterized as a research frontier - an extremely fruitful one.

2.4 Benefits

The benefits of the new production philosophy in terms of productivity, quality and other indicators have been tangible enough in practice to ensure a rapid diffusion of the new principles. However, the benefits have received surprisingly little study by scholars.

In a statistical study covering 400 manufacturing plants, mostly in the U.S. and Europe, it was found that of all the possible techniques for improving productivity, only those related to the new philosophy (termed JIT) are demonstrably effective (Schmenner 1988).

One of the best researched industries is car manufacturing (Womack & al. 1990). Lean car production is characterized as using less of everything compared with mass production: half the human effort in the factory, half the manufacturing space, half the investments in tools, half the engineering hours to develop a new product in half the time.

The same order of magnitude of benefits in other industries is substantiated by other authors. For example, improvement results from applying lean production in a wide variety of plants are reported by Schonberger (1986) and Harmon and Peterson (1990). Japanese companies have typically doubled factory productivity rates over a 5 year period while implementing the new principles (Stalk & Hout 1989). A reduction of manufacturing space by 50 % is a typical target (Harmon and Peterson 1990).

The competitive benefits created by means of the new approach seem to be remarkably sustainable. Toyota, the first adopter, has had a consistent lead in stock turnover and productivity as compared to its Japanese competitors (Lieberman 1990).

Table 1. Definitions of the new production philosophy.

Goals of the Toyota production system according to Monden (1983):

The Toyota production system completely eliminates unnecessary elements in production for the purpose of cost reduction. The basic idea is to produce the kind of units needed, at the time needed, and in quantities needed. The system has three subgoals:

1. Quantity control, which enables the system to adapt to daily and monthly fluctuations in terms of quantities and variety.
2. Quality assurance, which assures that each process will supply only good units to subsequent processes.
3. Respect for humanity, which must be cultivated while the system utilizes the human resource to attain its cost objectives.

The basic philosophy of the new production system according to the NPS Research Association (Shinohara 1988):

1. To seek a production technology that uses a minimum amount of equipment and labor to produce defect-free goods in the shortest possible time with the least amount of unfinished goods left over, and
2. To regard as waste any element that does not contribute to meeting the quality, price, or delivery deadline required by the customer, and to strive to eliminate all waste through concerted efforts by the administration, R&D, production, distribution, management, and all other departments of the company.

The organizational features of a lean plant according to Womack & al. (1990):

It transfers the maximum number of tasks and responsibilities to those workers actually adding value to the product on line, and it has in place a system for detecting defects that quickly traces every problem, once discovered, to its ultimate cause.

First law of manufacturing according to Plossl (1991):

In manufacturing operations, all benefits will be directly proportional to the speed of flow of materials and information.

Corollary 1: This law applies to every type of manufacturing business.
Corollary 2: The tightness of control of manufacturing activities will vary inversely with their cycle times.
Corollary 3: Any planning and control system will be more effective with fewer problems causing slower rates of materials and information.
Corollary 4: Solving one problem which slows down or interrupts material or information flow will cost less and be more effective than efforts to cope with the problem’s effects.

3 New production philosophy: conceptual basis

A basic tenet of this report is that lack of theoretical understanding has greatly hampered the diffusion of the new production philosophy to industries which do not have many similarities with car production. An explicit, preferably formalized theoretical basis is necessary for transfer of the new philosophy to new settings and for effective education.

In the following, we first define a production philosophy and then proceed to analyze the traditional production philosophy. After observing certain flaws in the traditional conceptual basis, the essential elements of the new production philosophy are presented. A number of design and improvement principles, implicit in the various practical approaches of the new production philosophy, are examined. Finally, other important implications of the new philosophy are considered.

3.1 What is a production philosophy?

The answer to the above question is not self-evident. As Bloch argues, this lack of definition may be associated with the fact that there is presently no science of manufacturing (Heim & Compton, p. 16). Rather, production has been seen as the task of applying existing technology in a systematic way.

A study (Heim & Compton 1992) by the Committee on Foundations of Manufacturing[1] is a noteworthy effort to define production philosophy, which the Committee calls "foundations of manufacturing":

> "The foundations for a field of knowledge provide the basic principles, or theories, for that field. Foundations consist of fundamental truths, rules, laws, doctrines, or motivating forces on which other, more specific operating principles can be based. While the foundations need not always be quantitative, they must provide guidance in decision making and operations. They must be action oriented, and their application should be expected to lead to improved performance."

Another interesting characterization is provided by Umble and Srikanth (1990), who require a manufacturing philosophy to contain the following elements:

- Definition of the common goal in terms that are understandable and meaningful to everyone in the organization.
- Development of the causal relationships between individual actions and the common global goal.
- Guidelines for managing the various actions so as to achieve the greatest benefit.

The discussion on paradigm shifts, initiated by Kuhn, is also valid for production philosophies. Paradigms, according to Kuhn (Smith & al. 1991):

- direct the ways problems are posed and solved
- indicate given assumptions
- indicate values, such as priorities and choice of problems and goals
- indicate exemplars which display the thinking.

Although originally used to refer to scientific activity, the term paradigm is now used in other contexts as well. In manufacturing, people have beliefs about good practice and models of the production process guiding their decisions and actions. However, due to the

[1] Assembled in 1989 by the National Academy of Engineering of the United States.

lack of an explicit production philosophy, such individual paradigms have often evolved from beliefs or rules of thumb that derive from personal experience (Heim & Compton 1992). They are often situation dependent and impossible to generalize or to apply in a new situation.

Paradigms are often implicit. They are adopted by a process of socialization into a craft or an organization, forming “practitioner’s knowledge”. This often makes it difficult to discuss the paradigm, or to argue for the need of a more detailed and accurate paradigm. However, the lack of an adequate paradigm can be recognized. A direct association of a solution to a problem often seems to indicate that the paradigm is too shallow; the many complexities of the situation are not perceived. Often paradigms are considered so self-evident that they hardly get mentioned. For example, textbooks in industrial engineering or construction engineering rarely begin with the foundations of the subject, but proceed to the treatment of individual techniques after introductory remarks.

However, there are several problems associated with implicit paradigms. Such paradigms are not generalizable or testable; their domain of feasibility is not known so applying them to new situations is problematic; their transfer and teaching is difficult. Thus, it is natural that the progress of a field often leads to increasing explicitness and formalization of the paradigm or philosophy.

Thus, in trying to understand the new philosophy, there is the dual task of uncovering the core in both the old and the new philosophies.

3.2 Conceptual basis of the conventional production philosophy

3.2.1 The conversion model

The conceptual model dominating the conventional view of production is the conversion model and its associated notions of organization and management. Up until recently these models have been self-evident, often implicit, and beyond criticism.

Production as a **conversion process** may be defined as follows:

1. A production process is a conversion of an input to an output.

Several disciplines (economics and industrial engineering, for example) have used this idea as a basis for understanding production. The model, illustrated in Figure 1, allows for convenient measurements, such as those of productivity, e.g. the ratio of output to the input (or a particular part of it) in a given time period. Thus, even if we do not have the conversion process in mind, our concepts and measurements often implicitly reflect this model.

However, for practical application to complex production situations, more features are needed. Though rarely stated explicitly, the following statements seem to be used in conjunction with the conversion model:

2. The conversion process can be divided into subprocesses, which also are conversion processes.
3. The cost of the total process can be minimized by minimizing the cost of each subprocess.
4. The value of the output of a process is associated with costs (or value) of inputs to that process.

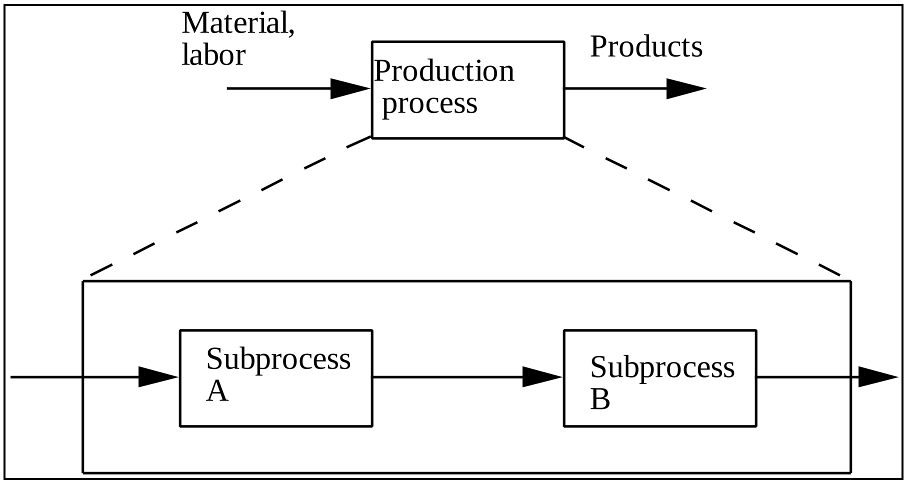

Figure 1. The conventional view of a production process as a conversion process that can be divided hierarchically into subprocesses.

Statements 2 and 3 are especially related to the theories of control in a hierarchical organization. Conventional accounting theory, which supports this mode of control, is based on the following assumptions (Umble & Srikanth 1990):

- total cost of the production process equals the sum of the costs of each operation
- the total cost of each operation (excluding material cost) is proportional to the cost of direct labor for that operation

This standard cost procedure is reversed when estimating the profitability of an equipment investment. If the labor cost of any operation can be reduced, the total cost will be reduced by both respective labor cost and the associated overhead cost. Thus the financial impact of any particular change on the whole production process can be determined. Attention can be focused on cost management in each operation, subprocess or department. In a hierarchical organization the costs of each organizational unit have thus to be minimized.

As suggested by statement 4, value is not very important in the traditional philosophy. Value of the output can be raised by using better material and more skilled specialists, the costs of which are higher. The following quote from an influential early accounting theoretician defines value: "...value of any commodity, service, or condition, utilized in production, passes over into the object or product for which the original item was expended and attaches to the result, giving it its value." (from Johnson & Kaplan 1987).

3.2.2 The conventional conceptual model is false

However, there are well-grounded theoretical arguments (Shingo 1988) and substantial empirical evidence from manufacturing which shows that the conversion process model, as applied to analyze and manage productive operations, is misleading or even false. The critique comes from two sources: JIT and TQC.

JIT critique

By focusing on conversions, the model abstracts away physical flows between conversions. These flows consist of moving, waiting and inspecting activities. In a way, this is a correct idealization; from the customer point of view these activities are not needed since they do not add value to the end product. However, in practice, the model has been interpreted so that (1) these non value-adding activities can be left out of consideration or (2) all activities are conversion activities, and are therefore treated as value-adding.

These erroneous interpretations are present in conventional production control methods and performance improvement efforts. The principle of cost minimization of each subprocess leads to the need for buffers that allow high utilization rates. It also leads to a situation where the impact of a particular subprocess on efficiency of other subprocesses tends to be unconsidered. Performance improvement is focused on improving the efficiency of subprocesses, typically with new technology. This, in turn, leads to improvement of and investment in non value-adding activities, which would be better suppressed or eliminated.

By focusing only on control and improvement of conversion subprocesses, the conversion model not only neglects, but even deteriorates overall flow efficiency. Unfortunately, in the more complex production processes, a major part of total costs are caused by flow activities rather than conversions. In fact, leading authorities in production control attribute the fact that "manufacturing is out of control in most companies" directly to the neglect of flows (Plossl 1991). In addition, poor ability to control manufacturing makes improving conversion processes more difficult: "Major investments in new equipment are not the solution to a confused factory" (Hayes & al. 1988).

Quality critique

The critique from the quality point of view addresses the following two features[2]:

- the output of each conversion is usually variable, to such an extent that a share of the output does not fulfill the implicit or explicit specification for that conversion and has to be scrapped or reworked
- the specification for each conversion is imperfect; it only partially reflects the true requirements of the subsequent conversions and the final customer.

The conversion model does not include these features, thus suggesting that they are not pertinent problems of production processes.

The consequences of the absence of the first feature are clear in practice: "about a third of what we do consists of redoing work previously 'done'"(Juran 1988).

The impact of the second conceptual failure is more subtle and concerns lost opportunities to fulfill customer requirements. In practice, the result is that improvement efforts are directed toward making conversions more efficient rather than making them more effective. Products which poorly fulfill customer requirements and expectations are then produced with great efficiency.

Note that although these problems are different than those analyzed from the JIT standpoint, they too ultimately impact physical flows. Quality deviations cause waste in themselves, but also through interruption of the physical flow. In a similar way, poorly defined requirements in internal customer-supplier relationships add to conversion time and costs and thus slow down the physical flow.

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[2]These two items correspond to the common views on quality (Juran 1988):

- conformance to the specification or freedom from deficiencies
- product performance.

3.2.3 Why has the conventional model been adopted?

Why has the conversion model been used in the first place, when its drawbacks, at least in hindsight, are so evident? A clue to a possible answer is given by Johnson and Kaplan (1987). The conversion model was established in the 19th century, when plants and companies were centered around just one conversion. Towards the end of the century, the trend was to form hierarchically organized companies, controlling several conversion processes. The organizational models and the accounting practices were developed to conform to the new requirements. Production processes were simpler, flows shorter and organizations smaller, so the problems due to the conceptual basis remained negligible. Only later, as the conversion model has been applied to more complex production, have the problems surfaced clearly.

3.3 Conceptual basis of the new production philosophy

The new conceptual model is a synthesis and generalization of different models suggested in various fields, like the JIT movement (Shingo 1984) and the quality movement (Pall 1987). Thus the task is to develop a model covering all important features of production, especially those that are lacking in the conversion model. The new production model can be defined as follows:

> Production is a flow of material and/or information from raw material to the end product (Figure 2). In this flow, the material is processed (converted), it is inspected, it is waiting or it is moving. These activities are inherently different. Processing represents the conversion aspect of production; inspecting, moving and waiting represent the flow aspect of production.
>
> Flow processes can be characterized by time, cost and value. Value refers to the fulfillment of customer requirements. In most cases, only processing activities are value-adding activities. For material flows, processing activities are alterations of shape or substance, assembly and disassembly.

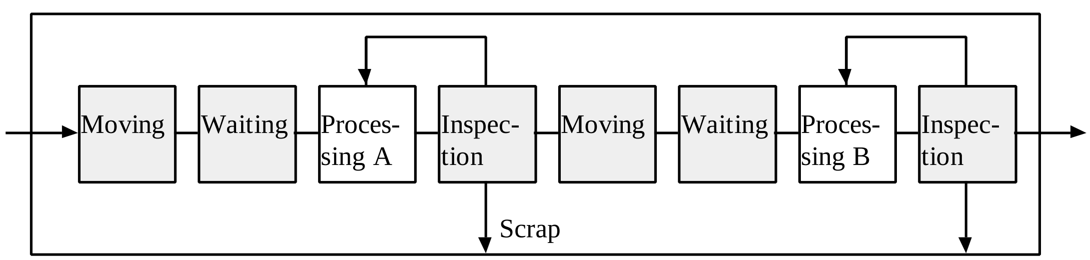

Figure 2. Production as a flow process: simplistic illustration. The shaded boxes represent non value-adding activities, in contrast to value-adding processing activities.

In essence, the new conceptualization[3] implies a dual view of production: it consists of conversions and flows. The overall efficiency of production is attributable to both the efficiency (level of technology, skill, motivation, etc.) of the conversion activities

[3] Note that there are several related definitions that only partially cover the important features considered here. For example the process definition of Pall (1987) - typical of the quality literature - does not cover the physical flow aspect. In the value chain of Porter (1990) all activities add value.

performed, as well as the amount and efficiency of the flow activities through which the conversion activities are bound together[4].

While all activities expend cost and consume time, only conversion activities add value to the material or piece of information being transformed to a product. Thus, the improvement of flow activities should primarily be focused their reduction or elimination, whereas conversion activities have to be made more efficient. This core idea of the new production philosophy is illustrated in Figure 3.

But how should flow processes be designed, controlled and improved in practice? In various subfields of the new production philosophy, the following heuristic principles have evolved:

1. Reduce the share of non value-adding activities.
2. Increase output value through systematic consideration of customer requirements.
3. Reduce variability.
4. Reduce the cycle time.
5. Simplify by minimizing the number of steps, parts and linkages.
6. Increase output flexibility.
7. Increase process transparency.
8. Focus control on the complete process.
9. Build continuous improvement into the process.
10. Balance flow improvement with conversion improvement.
11. Benchmark.

These principles are elaborated in the next section. In general, the principles apply both to the total flow process and to its subprocesses. In addition, the principles implicitly define flow process problems, such as complexity, intransparency or segmented control.

Note that it is rarely possible to devise the best possible process by design only; usually the designed and implemented process provides a starting point for continuous improvement, based on measurements of actual process behavior.

[4] In recent discussion on strategy, the former has been called core competence, the latter capability (Stalk & al. 1992).

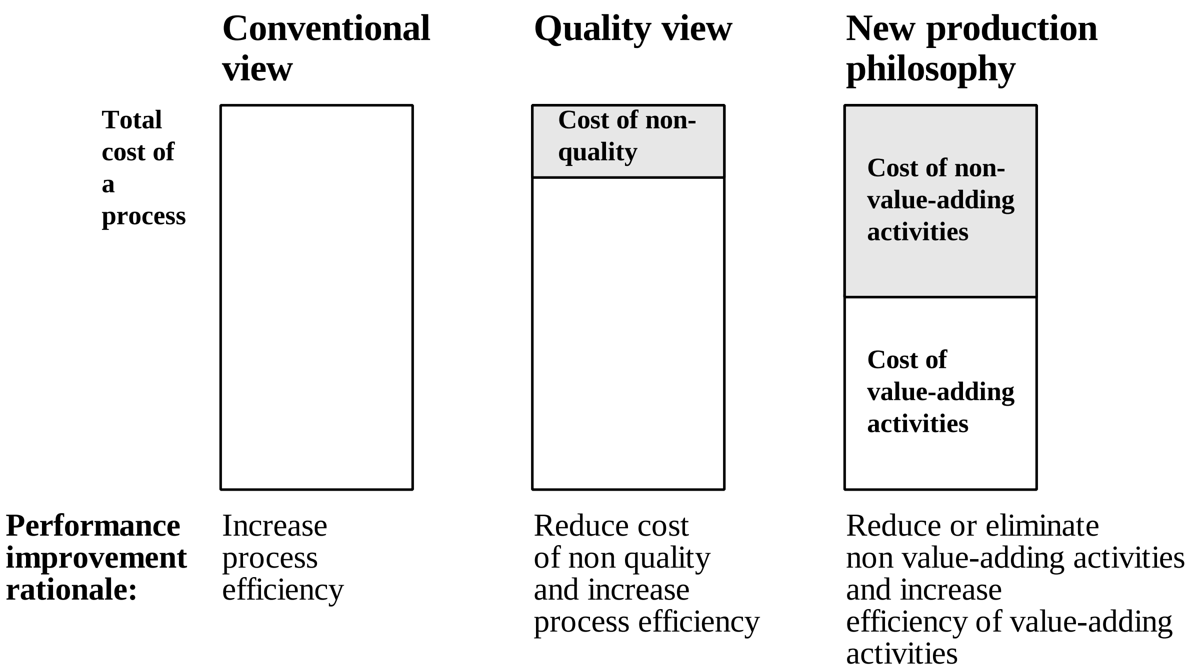

Figure 3. Performance improvement in conventional, quality and new production philosophy approaches. Note that the customary quality view addresses only a subset of all non value-adding activities.

3.4 Principles for flow process design and improvement

In the following, the eleven important principles for flow process design and improvement are examined.

Note, that most “buzzword approaches” to the new production philosophy have originated around one central principle. Even if they usually acknowledge other principles, their approach is inherently partial. Thus, for example, the quality approach has variability reduction as its core principle. Time based management endeavors to reduce cycle times. Value based management aims at increasing output value.

Many principles are closely related, but not on the same abstraction level. Some are more fundamental, while others more application oriented.

It is also important to note that the understanding of these principles is of very recent origin. It is presumed that knowledge of these principles will rapidly grow and be systematized.

3.4.1 Reduce the share of non value-adding activities

Value-adding and non value-adding activities can be defined as follows:

> Value-adding activity: Activity that converts material and/or information towards that which is required by the customer.
>
> Non value-adding activity (also called waste): Activity that takes time, resources or space but does not add value.

Reducing the share of non value-adding activities is a fundamental guideline. Experience shows that non value-adding activities dominate most processes; usually only 3 to 20 % of steps add value (Ciampa 1991), and their share of the total cycle time is negligible, from 0.5 to 5 % (Stalk & Hout 1990). Why are there non value-adding activities in the first place? There seems to be three root causes: design, ignorance and the inherent nature of production.

Non value-adding activities exist by design in hierarchical organizations. Every time a task is divided into two subtasks executed by different specialists, non value-adding activities increase: inspecting, moving and waiting. In this way, traditional organizational design contributes to an expansion of non value-adding activities.

Ignorance is another source of non value-adding activities. Especially in the administrative sphere of production, many processes have not been designed in an orderly fashion, but instead just evolved in an *ad hoc* fashion to their present form. The volume of non value-adding activities is not measured, so there is no drive to curb them.

It is in the nature of production that non value-adding activities exist: work-in-process has to be moved from one conversion to the next, defects emerge, accidents happen.

With respect to all three causes for non value-adding activities, it is possible to eliminate or reduce the amount of these activities. However, this principle cannot be used simplistically. Some non value-adding activities produce value for internal customers, like planning, accounting and accident prevention. Such activities should not be suppressed without considering whether more non value-adding activities would result in other parts of the process. However, accidents and defects, for example, have no value to anybody and should be eliminated without any hesitation.

Most of the principles presented below address suppression of non value-adding activities. However, it is possible to directly attack the most visible waste just by flowcharting the process, then pinpointing and measuring non value-adding activities[5].

3.4.2 Increase output value through systematic consideration of customer requirements

This is another fundamental principle. Value is generated through fulfilling customer requirements, not as an inherent merit of conversion. For each activity there are two types of customers, the next activities and the final customer.

Because this sounds self-evident, we again have to ask why customer requirements have not been considered.

The organizational and control principles of the conventional production philosophy have tended to diminish the role of customer requirements. In many processes, customers have never been identified nor their requirements clarified. The dominant control principle has been to minimize costs in each stage; this has not allowed for optimization of cross-functional flows in the organization.

The practical approach to this principle is to carry out a systematic flow design, where customers are defined for each stage, and their requirements analyzed. Other principles,

[5] A detailed methodology for administrative processes is presented, for example, by Harrington (1991).

especially enhanced transparency and continuous improvement, also contribute to this principle.

3.4.3 Reduce variability

Production processes are variable. There are differences in any two items, even though they are the same product, and the resources needed to produce them (time, raw material, labor) vary.

There are two reasons for reducing process variability. First, from the customer point of view a uniform product is better. Taguchi proposes that any deviation from a target value in the product causes a loss, which is a quadratic function of the deviation, to the user and wider society (Bendell & al. 1989). Thus, reduction of variability should go beyond mere conformance to given specifications.

Secondly, variability, especially of activity duration, increases the volume of non value-adding activities. It may easily be shown through queue theory that variability increases the cycle time (Krupka 1992, Hopp & al. 1990). Indeed, there are no instances where more variability is good (Hopp & al. 1990).

Thus, reduction of variability within processes must be considered an intrinsic goal (Sullivan 1984). Schonberger (1986) states strongly: "Variability is the universal enemy." Alternative expressions for this principle are: reduce uncertainty, increase predictability.

The practical approach to decreasing variability is made up of the well-known procedures of statistical control theory. Essentially, they deal with measuring variability, then finding and eliminating its root causes. Standardization of activities by implementing standard procedures is often the means to reduce variability in both conversion and flow processes. Another method is to install fool-proofing devices ("poka-yoke") into the process (Shingo 1986).

3.4.4 Reduce the cycle time

Time is a natural metric for flow processes. Time is a more useful and universal metric than cost and quality because it can be used to drive improvements in both (Krupka 1992).

A production flow can be characterized by the cycle time, which refers to the time required for a particular piece of material to traverse the flow[6]. The cycle time can be represented as follows:

Cycle time = Processing time + inspection time + wait time + move time

The basic improvement rationale in the new production philosophy is to compress the cycle time, which forces the reduction of inspection, move and wait time. The progression of cycle time reduction through successive process improvement is depicted in Figure 4.

In addition to the forced elimination of wastes, compression of the total cycle time gives the following benefits (Schmenner 1988, Hopp & al. 1990):

- faster delivery to the customer
- reduced need to make forecasts about future demand

[6] There often are several flows which unite or diverge in the total production process. However, it is generally possible to recognize the main flow and side flows, which have to be assessed separately.

- decrease of disruption of the production process due to change orders
- easier management because there are fewer customer orders to keep track of.

The principle of cycle time compression also has other interesting implications. From the perspective of control, it is important that the cycles of deviation detection and correction are speedy. In design and planning, there are many open-ended tasks that benefit from an iterative search for successively better (if not optimal) solutions. The shorter the cycle time, the more cycles are affordable.

From the point of view of improvement, the cycle time from becoming conscious of a problem or an opportunity to the implementation of a solution is crucial. In traditional organizations, this cycle time is sometimes infinite due to lack communication where no message is passed, or a long channel of communication where the message gets distorted.

Every layer in an organizational hierarchy adds to the cycle time of error correction and problem solving. This simple fact provides the new production philosophy's motivation to decrease organizational layers, thereby empowering the persons working directly within the flow.

Practical approaches to cycle time reduction include the following (for example, Hopp & al. 1990, Plossl 1991, Stalk & Hout 1990)):

- eliminating work-in-progress (this original JIT goal reduces the waiting time and thus the cycle time)
- reducing batch sizes
- changing plant layout so that moving distances are minimized
- keeping things moving; smoothing and synchronizing the flows
- reducing variability
- changing activities from sequential order to parallel order
- isolating the main value-adding sequence from support work
- in general, solving the control problems and constraints preventing a speedy flow.

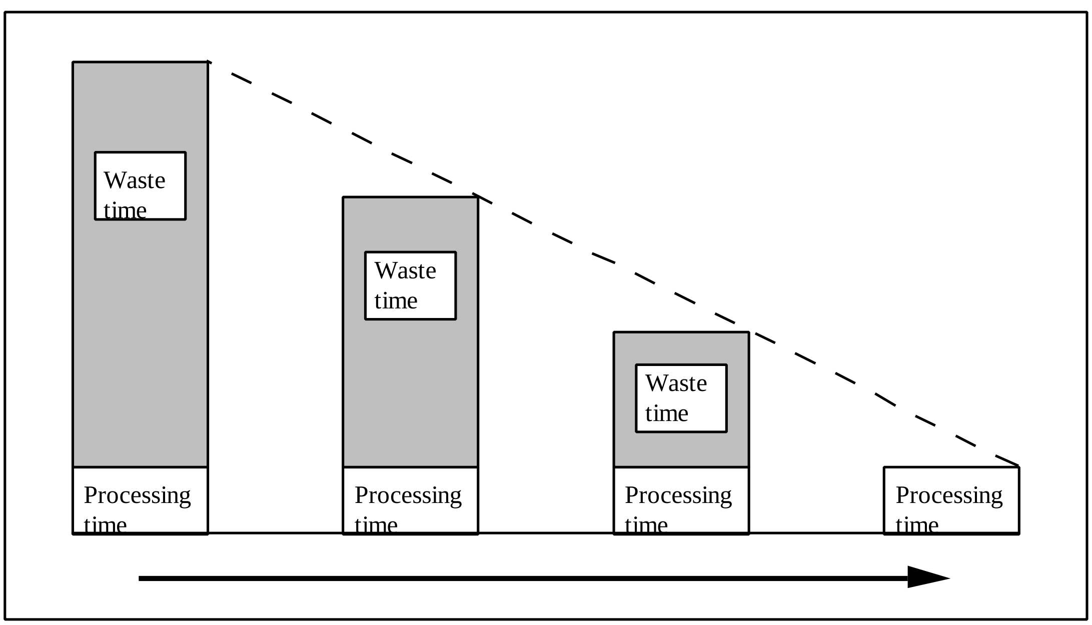

Figure 4. Cycle time can be progressively compressed through elimination of non value-adding activities and variability reduction (Berliner & Brimson 1988).

3.4.5 Simplify by minimizing the number of steps and parts

Other things being equal, the very complexity of a product or process increases the costs beyond the sum of the costs of individual parts or steps. Conventional accounting shows the price differential of two materials, but not the additional costs created in the whole production system by using two instead of one (Child & al. 1991). Another fundamental problem of complexity is reliability: complex systems are inherently less reliable than simple systems. Also, the human ability to deal with complexity is bounded and easily exceeded.

Simplification can be understood as

- reducing of the number of components in a product
- reducing of the number of steps in a material or information flow

Simplification can be realized, on the one hand, by eliminating non value-adding activities from the production process, and on the other hand by reconfiguring value-adding parts or steps.

Organizational changes can also bring about simplification. Vertical and horizontal division of labor always brings about non value-adding activities, which can be eliminated through self-contained units (multi-skilled, autonomous teams).

Practical approaches to simplification include:

- shortening the flows by consolidating activities
- reducing the part count of products through design changes or prefabricated parts
- standardizing parts, materials, tools, etc.
- decoupling linkages
- minimizing the amount of control information needed.

3.4.6 Increase output flexibility

At first glance, increase of output flexibility seems to be contradictory to simplification. However, many companies have succeeded in realizing both goals simultaneously (Stalk & Hout 1990). Some of the key elements are modularized product design in connection with an aggressive use of the other principles, especially cycle time compression and transparency.

Practical approaches to increased flexibility include (Stalk & Hout 1990, Child & al. 1991):

- minimizing lot sizes to closely match demand
- reducing the difficulty of setups and changeovers
- customizing as late in the process as possible
- training a multi-skilled workforce.

3.4.7 Increase process transparency

Lack of process transparency increases the propensity to err, reduces the visibility of errors, and diminishes motivation for improvement. Thus, it is an objective to make the production process transparent and observable for facilitation of control and improvement: “to make the main flow of operations from start to finish visible and comprehensible to all employees” (Stalk & Hout 1989). This can be achieved by making the process directly observable through organizational or physical means, measurements, and public display of information.

In a theoretical sense, transparency means a separation of the network of information and the hierarchical structure of order giving (Greif 1991), which in the classical organization theory are identical. The goal is thus to substitute self-control for formal control and related information gathering.

Practical approaches for enhanced transparency include the following:

- establishing basic housekeeping to eliminate clutter: the method of 5-S[7]
- making the process directly observable through appropriate layout and signage
- rendering invisible attributes of the process visible through measurements
- embodying process information in work areas, tools, containers, materials and information systems
- utilizing visual controls to enable any person to immediately recognize standards and deviations from them
- reducing the interdependence of production units (focused factories).

3.4.8 Focus control on the complete process

There are two causes of segmented flow control: the flow traverses different units in a hierarchical organization or crosses through an organizational border. In both cases, there is a risk of suboptimization.

There are at least two prerequisites for focusing control on complete processes. First, the complete process has to be measured.

Secondly, there must a controlling authority for the complete process. Several alternatives are currently used. In hierarchical organizations, process owners for cross-functional processes are appointed, with responsibility for the efficiency and effectiveness of that process (Rummler & Brache 1990). A more radical solution is to let self-directed teams control their processes (Stewart 1992).

For inter-organizational flows, long term co-operation with suppliers and team building have been introduced with the goal of deriving mutual benefits from an optimized total flow.

3.4.9 Build continuous improvement into the process

The effort to reduce waste and to increase value is an internal, incremental, and iterative activity, that can and must be carried out continuously. There are several necessary methods for institutionalizing continuous improvement:

- Measuring and monitoring improvement.
- Setting stretch targets (e.g. for inventory elimination or cycle time reduction), by means of which problems are unearthed and their solutions are stimulated.
- Giving responsibility for improvement to all employees; a steady improvement from every organizational unit should be required and rewarded.
- Using standard procedures as hypotheses of best practice, to be constantly challenged by better ways.
- Linking improvement to control: improvement should be aimed at the current control constraints and problems of the process. The goal is to eliminate the root of problems rather than to cope with their effects.

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[7] The method of 5-S takes its name from the initials of five Japanese words referring to organization, orderliness, cleanliness, personal cleanliness and discipline (Imai 1986). The method is used for creating a basic workplace organization.

Continuous improvement is analyzed in more detail in section 3.5.

3.4.10 Balance flow improvement with conversion improvement

In the improvement of productive activities, both conversions and flows have to be addressed. But how should these two alternatives be balanced?

For any production process, the flow and conversion aspects each have a different potential for improvement. As a rule,

- the higher the complexity of the production process, the higher the impact of flow improvement
- the more wastes inherent in the production process, the more profitable is flow improvement in comparison to conversion improvement.

However, in a situation where flows have been neglected for decades, the potential for flow improvement is usually higher than conversion improvement. On the other hand, flow improvement can be started with smaller investments, but usually requires a longer time than a conversion improvement.

The crucial issue is that flow improvement and conversion improvement are intimately interconnected:

- better flows require less conversion capacity and thus less equipment investment
- more controlled flows make implementation of new conversion technology easier
- new conversion technology may provide smaller variability, and thus flow benefits.

Therefore one is tempted to agree with Ohno, who argues that “improvement adheres to a certain order” (Ohno 1988). It is often worthwhile to aggressively pursue flow process improvement before major investments in new conversion technology: “Perfect existing processes to their full potential before designing new ones” (Blaxill & Hout 1991). Later, technology investments may be aimed at flow improvement or redesign.

3.4.11 Benchmark

Unlike technology for conversions, the best flow processes are not marketed to us; we have to find the world class processes ourselves.

Often benchmarking is a useful stimulus to achieve breakthrough improvement through radical reconfiguration of processes. It helps to overcome the NIH-syndrome and the power of ingrained routines. By means of it, fundamental logical flaws in the processes may be unearthed[8].

The basic steps of benchmarking include the following (Camp 1989):

- knowing the process; assessing the strengths and weaknesses of subprocesses
- knowing the industry leaders or competitors; finding, understanding and comparing the best practices
- incorporating the best; copying, modifying or incorporating the best practices in your own subprocesses

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[8] Through benchmarking, Ford Company observed that Mazda’s accounts payable department was run by 5 persons, in comparison to Ford’s over 500 employees (Hammer 1990). Ford’s accounts payable function was then radically “re-engineered” by simplifying the procedures and by implementing “invoice-less processing”. It was realized that the objective of the department, “payment upon invoice” was not appropriate any more, and a new goal “paying upon delivery” was adopted.

- gaining superiority by combining existing strengths and the best external practices.

A detailed methodology for benchmarking is presented by Camp (1989).

3.5 Continuous improvement vs. innovation

Many of the principles discussed above are realized in the framework of continuous improvement. Because the concept is relatively new, it is useful to analyze and compare it with innovation, which has been the primary framework of analysis until now.

The Western view on technological advancement has seen product and process[9] innovation as the prime movers of change. Characteristic to both product and process innovation is that the innovative features are embodied in a product or in production equipment. Most often, innovation is stimulated by external technological development or market demand. Innovation is often seen as a breakthrough leap, though incremental refinement is also accepted as a form of innovation. In many disciplines, like economics and industrial engineering, the residual technological progress that remains unexplained by innovation has been called learning.

Imai (1986) argues that this conceptual framework of innovation has prevented the understanding of the significance of continuous improvement, characterized by incremental steps, wide internal involvement and organization-embodied innovation (Table 2).

Table 2. Comparison of innovation and continuous improvement (modified from Imai (1986)).

	Innovation	*Continuous improvement*
Focus	Efficiency of conversions	Efficiency of flow processes
Goal	Leaps in efficiency	Small steps, details, finetuning
Involvement	Company and outside specialists, champions	Everybody in the company
Time frame	Intermittent and non-incremental	Continuous and incremental
Technology relied upon	Outside technological breakthroughs, new inventions, new theories	Internal know-how, best practice
Incentive	New superior technology or need for capacity extension	Overcome constraints in variability reduction or cycle time compression
Practical requirements	Requires large investment, but little effort to maintain it	Requires little investment, but great effort to maintain it
Mode of action	Scrap and rebuild	Maintenance and improvement
Transferability	Transferable: embodied in individual equipment and related operating skill	Primarily idiosyncratic: embodied in system of equipments, skills, procedures and organization
Effort orientation	Technology	People

To some extent continuous improvement parallels the traditional view on innovation: they both incorporate incremental product and conversion process improvement. However, continuous improvement is more geared towards development of the flow process than

[9] In innovation literature, the term “process innovation” refers to conversion process innovation rather than to flow process innovation.

conversions (Figure 5). On the other hand, in some cases an innovation may enhance the efficiency of the flow process.

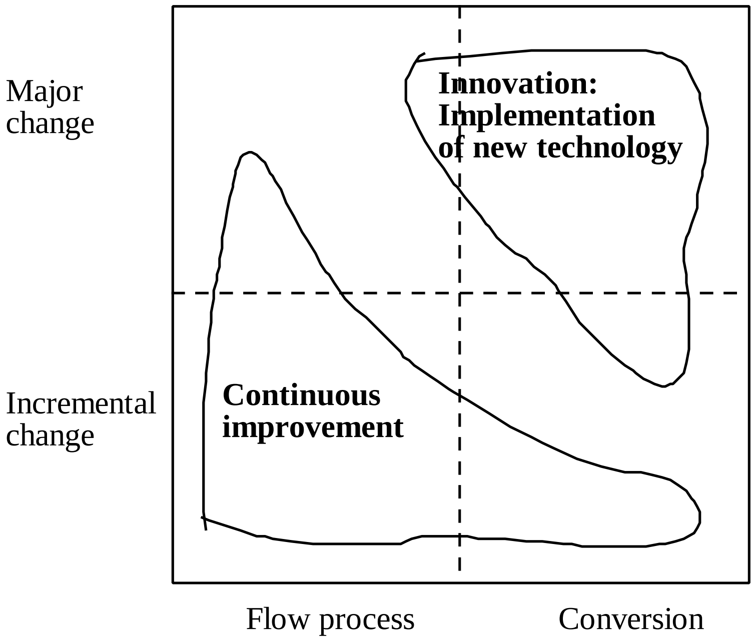

Figure 5. Continuous improvement and innovation: focus and aimed change.

The focus of continuous improvement is typically:

- eliminating bottlenecks (elaborated in the theory of constraints (Umble & Srikanth 1990))
- variability reduction
- cycle time reduction
- elimination of non value-adding steps from the flow
- ongoing consideration of customer requirements for each activity.
- finetuning different parts of the process for better synchronization
- maintenance for better reliability
- incremental development of equipment (procured from outside or self-fabricated).

In practice, innovation-oriented performance improvement is seen as an ongoing series of decisions as to whether the probable gain from each proposed improvement activity, independently considered, will exceed the expenditure to implement it (Hall & al. 1991). Only clear-cut investments in new machinery capable of showing productivity gains tend to overcome this hurdle of justification. Organizationally, performance improvement is strictly separated from control and does not address problems of control. Thus, performance improvement activities remain unfocused and limited in their scope.

As argued earlier, the interaction between continuous improvement and innovation has to be acknowledged. Poor flow efficiency is a barrier to innovation, because the benefits of an innovation become invisible in the confused environment. Implementation is difficult when there are many intervening disturbances (Hayes & al. 1988, Chew & al. 1991). This is related to the argument that there is a preferred sequence of improvement and innovation (Ohno 1982). Only after exhausting incremental innovation potential are major changes suggested.

Thus, the new production philosophy provides a vision and focus for improvement and innovation. It stresses improvement directed at the present constraints in the production flow.

3.6. Measurements in continuous improvement

Measures are extremely important in the pursuit of lean production. Measures provide access to continuous improvement by pinpointing improvement potential and monitoring progress achieved.

The traditional measures that most often focus on costs, productivity or utilization rates, have been criticized from several points of view. Their major problems include the following:

- they do not give impetus for continuous improvement
- they do not attempt to understand the sources of indirect costs and thus misdirect attention; for example, the principle of allocating overhead cost in proportion to direct labor focuses the cost reduction attention solely to direct labor (Johnson & Kaplan 1987)
- they lead to local optima instead of the global optimum (Umble & Srikanth 1990)
- they measure after the fact
- there is a tendency to collect too much data, especially in the framework of computerized systems (Plossl 1991).

In lean production, measurements should support the application of the new principles. Thus, there are a number of requirements for measurements:

- Waste reduction. The measurement system should be able to measure waste inherent in the process.
- Adding value. The measurement system should be able to measure value added by each step in the process.
- Variability reduction. Measurement of variability and defects is necessary.
- Cycle time. Cycle time for the main process and the various side and subprocesses has to be measured.
- Simplification. Measures for complexity/simplicity have to be developed and applied.
- Transparency. Measurements should be close to each activity so that the people performing each activity receive direct, immediate and relevant feedback (Harrington 1991). Invisible features of the process have to be made visible by measurements. Both global and local measures should be provided for each activity.
- Focus on complete process. Both the process and the product should be measured. Measurements should focus on causes rather than results, e.g. costs (Schonberger 1990).
- Continuous improvement. The measurement system should be able to measure the status and rate of process improvement (Hayes & al. 1988). Measures should be capable of pinpointing the potential for improvement. Measures should foster improvement rather than just monitor it (Maskell 1991). Trends are more important than absolute values.

Some of the new principles are also applicable to measurement itself:

- Simplification. Measurement should not require much additional effort. There should not be too many different measures. After all, measurement does not directly add value to the product.

- Measures should be transparent and understandable. Aggregates are better than details, physical measures better than financial, and visual feedback is more useful than systems data (Plossl 1991).

Non financial, physical measurements that directly reflect the status of improvement activities are emphasized (Plossl 1991, Maskell 1991). While costs are based on a number of physical factors, it is impossible to influence these through cost control; however, it is possible the other way around, to influence cost through manipulating physical factors.

Time as a suitable global measuring dimension is suggested by Stalk and Hout (1990) and other authors. Related measures include

- cycle time (per major subprocess)
- inventory turnover
- value-added time as percent of total elapsed time
- decision cycle time
- lead time (from order to delivery)
- schedule performance (meeting daily schedule).

Some authors argue for the need to tailor measurements closely to the requirements of the situation. Measurements should vary between locations even within one firm, and they should change over time (Maskell 1991). For example, quality costs may be a good measure in initial phases as a motivation, but for continuous, operational use it might be too laborious.

3.7 Implementation of the new philosophy

Even if there are numerous examples of successful implementation of the new philosophy, there also are examples of failures and false starts. After all, the majority of companies has not yet launched full scale efforts for adopting these ideas.

There are emotional and conceptual barriers for implementation. Ashton & al. (1990) argue that many managers derive their perceived knowledge from their position in the organization and they fear that their actual lack of knowledge would be exposed. Conceptual barriers are related to the difficulty of abandoning the conventional assumptions concerning organizing, controlling, etc.

Experience shows that there are four key factors that have to be balanced in implementing the new philosophy (the framework is based on Ashton & al. (1990), Schaffer & Thomson (1992), and Plossl (1991)):

1. Management commitment

Leadership is needed to realize a fundamental shift of philosophy, with the goal of improving every activity in the organization. Without an active initiative from the management, change will stop at all natural barriers. Management must understand and internalize the new philosophy. The change will be realized only through people; it cannot be delegated to staff specialists, like in the case of investment into new technology.

Management must create an environment which is conducive to change. As Deming (1982) says, there must be constancy of purpose.

2. Focus on measurable and actionable improvement

The focus should be on actionable and measurable improvement, rather than just on developing capabilities. Of course, defining various flow processes and focusing on their bottlenecks to speed up and smooth out material and information flows means just that. Short term successes then reinforce motivation for further improvement.

Originally in JIT, the overarching goal was to reduce or eliminate inventories. However, reduction of inventories uncovered other problems, which had to be solved as a forced response. Cycle time, space and variability have also been used as drivers, because they too are increased by underlying problems. Especially cycle time provides an excellent, easy to understand driver, which can be improved continually.

3. Involvement

Employee involvement happens naturally, when organizational hierarchies are dismantled, and the new organization is formed with self-directed teams, responsible for control and improvement of their process (Stewart 1992). But also even if the hierarchy remains intact, involvement can be stimulated through problem solving teams.

However, Shingo (1988) and Imai (1986) stress that management and staff specialists have a dominant role in targeting and realizing the improvement. Employee involvement is thus necessary, but not sufficient for realizing the full potential of continuous improvement.

4. Learning

Implementation requires a substantial amount of learning. First, learning should be directed at principles, tools and techniques of process improvement. In the next phase, the focus turns to empirical learning from manipulating the processes. For this reason, formal reviews of progress and experiences are useful. One form of learning consists of pilot projects for testing new ideas on a limited scale. A third source of learning is made up by external information, which can be tapped through benchmarking.

Lack of balance among these four factors leads usually to a dead end. For example:

- lack of management’s commitment and changed priorities will be rapidly visible and demotivate other parties
- primary emphasis on learning and involvement, without simultaneous attack on real, urgent problems, does not lead to bottom line results (Schaffer & Thomson 1992).

3.8 Conclusions

The traditional and the new production philosophies are summarized in Table 3.

The core of the new production philosophy is in the observation that there are two kinds of phenomena in all production systems: conversions and flows. In the design, control and improvement of production systems, both aspects have to be considered. Traditional managerial principles have considered only conversions, or all activities have been treated as though they were value-adding conversions.

Due to these traditional managerial principles, flow processes have not been controlled or improved in an orderly fashion. This has led to complex, uncertain and confused flow processes, expansion of non value-adding activities, and reduction of output value.

Eleven principles for flow process design and improvement have evolved. There is ample evidence that through these principles, the efficiency of flow processes can be considerably and rapidly improved.

Table 3. The traditional and new production philosophies.

The traditional production philosophy
Production activities are: - conceived as sets of **operations or functions**, which are - controlled, operation-by-operation, for **least costs**, and - improved **periodically** with respect to **productivity** by implementing **new technology**.
The new production philosophy
Production activities are: - conceived as material and information **flow processes**, which are - controlled for minimal **variability and cycle time**, and - improved **continuously** with respect to **waste and value**, and periodically with respect to efficiency by implementing new technology.

4 Construction as activity

To what degree do the problems associated with the conventional production view, as observed in manufacturing, also exist in construction? This is the basic question we address in this chapter. To answer it, we first analyze the traditional conceptual basis of construction, and then discuss the problems caused by these traditional concepts. Available information on wastes in construction is summarized, and the detrimental impact of the traditional concepts on development efforts in construction is presented.

4.1 The traditional conceptualization of construction

Construction is a very old industry. Its culture and many of its methods have their roots in periods before explicit scientific analysis. However, especially after the Second World War, there have been several different initiatives to understand construction and its problems and to develop corresponding solutions and improvement methods. We can recognize strategic initiatives like industrialization, computer integrated construction, and total quality management. We also see operational and tactical techniques such as project planning and control tools, organizational methods, project success factors, and productivity improvement methods. What conceptualizations have been used in these efforts by practicing builders and researchers?

By far the most general concept seems to be the understanding of construction as a set of activities aimed at a certain output, i.e. conversions. This activity view of construction is shared both by the old traditions of construction and the newer methods.

The traditional method of cost estimation is at the heart of this activity view. The building (or other structure) is divided into its constituent elements, and for each element, the costs of needed materials and labor (conversion of input to output) are estimated. In later stages, contracts which specify a part of the building as the output, and a remuneration as input, are established. This is exactly according to the conversion model: it is assumed that the total production process consists of a set of subprocesses which convert an input to an output, and which can be realized and analyzed in isolation from each other[1]. Also in network based project planning (CPM networks), a relative newcomer in the historical perspective of construction, the activities needed for producing the various elements of the building are the basic unit of analysis.

This activity view is the basis for several managerial concepts in construction that are also seen in manufacturing. A sequential mode of project realization, hierarchical organization, and neglect of quality issues are such concepts.

That construction has been based on the conversion model is further supported by cases where unexpected interaction between activities is observed. The great influence of design on construction and operating costs was first pointed out and analyzed as recently as 1976 (Paulson 1976). Friedrich et al. (1987) strongly criticize the customary notion that large projects can be measured using yardsticks viewed as simple summations of individual yardsticks taken discipline by discipline, system by system, or component by component.

[1] Even the newest theory formation is based on this. Bennett presents in his recent book (1991) a general theory of construction project management. His basic unit of analysis is days-work: “The whole point and purpose of construction project management is to create conditions that enable the teams who make up project organizations to carry out days-work efficiently.”

Thus, the overall effects of revisions, repairs, and rework on large projects can be very significant, even when the individual effects of specific functions and disciplines appear small and within “normal” acceptable practices.

Beyond this conversion model, what theories or frameworks have been used in construction? As odd as it might seem, there are hardly any other theoretical or conceptual frameworks in general use. As elaborated below, this conclusion is suggested by textbook content, research content, and discussions by other construction researchers.

Even a rapid glance at the contents of textbooks on construction management shows that they usually begin with a descriptive account of a construction project (Clough & Sears 1991, Barrie & Paulson 1986) and then proceed to specific techniques of management and control. No major conceptual or theoretical analysis of construction is provided at the outset.

The research into construction project success factors endeavors to find the factors that are important for achieving outstanding project results. Because of its integrative nature, we could justifiably anticipate that the existing conceptual frameworks and theories are synthesized in that research. However, studies undertaken (Ashley & al. 1987, Jaselskis & Ashley 1991) are purely empirical, with little theoretical emphasis.

This lack of construction related theories has not gone unobserved by researchers. The lack of sufficient conceptual framework for construction project organizational design has been discussed by Sanvido (1988). Laufer and Tucker (1987) suggest an overall re-examination of the philosophy of project management.

This lack of a unified conceptual and theoretical framework has been persistent in spite of the growing realization of the flaws of the activity model.

We do need to acknowledge that there have been some flow oriented approaches in construction. Especially in heavy civil engineering practice as well as research, flows of material and equipment have been the framework of analysis. In addition, discrete event simulation of site activities has addressed flow characteristics (Halpin 1976, Bernold 1989). However, these are exceptions in the otherwise activity-oriented mind set of construction.

4.2 Flow problems caused by conventional managerial concepts

Criticisms of the conventional managerial concepts may be structured into three groups: sequential method of project realization, lack of quality considerations and segmented control. From manufacturing, there is overwhelming evidence of the counterproductive effects of these managerial principles. In addition to these generic managerial concepts, CPM (critical path method) network methods are a fourth specific problem source in construction. **These managerial principles violate principles of flow process design and improvement, and thus lead to non-optimal flows and an expansion of non value-adding activities.**

The flaws of these methods have been observed to varying degrees and alternatives have been sought. However, lacking a sound theory, these efforts have remained insufficient.

4.2.1 Sequential method of design and engineering

In sequential design and engineering, the total task is divided into temporally sequential tasks, which are given to different specialists for execution. This has been the conventional method of organizing product development in manufacturing. In construction, the traditional approach to project execution (for example, Barrie & Paulson 1984) is similar. Here, the client first selects an architect, who prepares overall designs and specifications. Designs for structural and mechanical disciplines are then prepared. Construction is the responsibility of a general contractor under contract to the client.

The problems of the traditional, sequential approach to construction have been widely discussed in recent years. However, what has not been generally realized is that this procedure leads to several generic flow process problems (based on Dupagne 1991):

- there are few or no iterations in the design process (long cycle times)
- constraints of subsequent phases are not taken into account in the design phase (poor consideration of requirements of next internal customers)
- unnecessary constraints for subsequent phases are set in the design phase (poor consideration of requirements of next internal customers)
- little feedback for specialists (poor process transparency, segmented project control)
- lack of leadership and responsibility for the total project (segmented project control).

Consequentially, the sequential procedure leads to

- suboptimal solutions
- poor constructability and operability
- large number of change orders (and thus rework in design and construction)
- lack of innovation and improvement.

4.2.2 Traditional approaches to quality

In conventional managerial approaches,

- no special effort is made to eliminate defects, errors, omissions, etc. and to reduce their impact, or
- it is thought that a fixed optimal level of quality exists.

It is now generally accepted that without special consideration, the cost of poor quality in average business operations is considerable. Figures in the range of 20 - 50 % are mentioned. This has also been substantiated in construction, as discussed in Section 4.3, below. Because processes in construction frequently have only one run, making continuous improvement is difficult, and the impacts of quality problems are accentuated.

Processes with quality problems are characterized by

- excessive variability
- poor deviation detection (long cycle time from detection to correction)
- insufficient consideration of customer requirements.

4.2.3 Segmented control

In the conventional approach, parts of a flow process are controlled rather than the whole. More often than not, the reason for this is the hierarchical organization.

Control in a hierarchical organization focuses on an organizational unit or a task, the costs of which are to be minimized. This leads to maximization of utilization rates and to large batches. This mode of control is characterized by both accumulation of work-in-process between units or operations and disruptions due to material or information shortages. The situation is further aggravated by specialization which leads to an increase in the number of units or tasks.

A typical construction example may be found in materials management (Oglesby & al. 1989). Responsibility for different tasks related to the preparation of a material flow is often divided among several persons. Purchasing of materials is often handled by a special department, which aims at minimizing the total purchase and transportation costs for each material. The resultant material flow is therefore not likely to be optimal from the point of view of site operations.

The disadvantages caused by this are:

- space and attention required for materials and work-in-progress (WIP), deterioration of WIP through natural elements, loss due to misplacement, theft, etc.
- error correction is too slow
- multiple handling.

Improvements that require co-operation from several units are very difficult to make under these circumstances.

4.2.4 Network planning

Network planning requires the division of flows into specific activities, which are then organized into a sequence providing for the (apparently) shortest duration.

Let us consider an activity in a CPM network. An activity is usually a part of the overall work flow of a team or it is a complete work flow in itself. It is usually fed by a material flow.

When an activity is a part of a wider work flow, it is strongly affected by the previous activity. The work team has to move from the previous location, and if the activities are the same, learning benefits are gained and the set-up time reduced. The cost of supervision and control also depends on the continuity of the work flow. CPM networks do not generally model these issues.

When an activity is a complete work flow (say, installation of an elevator), the network method just determines the starting time, but does not plan the flow itself.

Thus, traditional network planning fails to support the planning of work flows of teams or material flows and may lead to suboptimal flows. Neither work flows of teams nor material flows are planned in a consistent way (Birrell 1980, 1986). Stated briefly, disruptive disconnects in these flows are bound to result.

4.2.5 Neglect of flow control and improvement

One could say that the picture given above is too selective and negative; the flow aspects are certainly taken into account by seasoned practitioners.

To some extent, this is true. Take work flow control as an example. Birrell (1980) reports that in practice project planning is done by considering the spatial work flow of teams, rather than by CPM network analysis.

However, there is an overwhelming amount of contrary evidence. Whatever flow in construction we analyze, a tradition of neglect and mismanagement is found:

- Project planning: Owners start lump sum projects with absurd uncertainties (Laufer 1991). The detrimental impact of changes is not realized: “the true impact of changes is not well understood and seldom fully recognized in terms of cost and schedule adjustments” (Hester & al. 1991). Work hours for changes are underestimated by as much as 40 to 50 percent.
- Construction planning: “Today, it is the unusual contractor who does formal preplanning” (Oglesby, Parker & Howell 1989). On the contrary, construction planning should ensure smooth information, material and work flows.
- Materials management: This is found to be generally neglected (Oglesby, Parker & Howell 1989). “...many small- and medium sized contractors do not readily accept the notion that their profitability can be substantially improved through better material management” (Thomas, Sanvido, Sanders 1990). “...few materials-management systems are presently being effectively utilized by the industry” (Bernold & Treseler 1991).
- Work flows: Successful application of methodical work improvement, based on Taylor’s scientific work study, was first reported in 1911 (Drewin 1982). However, the authors of a leading volume in productivity improvement state in 1989 that “adoptions [of techniques for improving productivity have] seldom occurred (Oglesby, Parker, Howell 1989).

This state of affairs has not emerged by chance, but rather as a result of a mind set which has not observed and analyzed the flow aspects of construction properly.

4.2.6 Compound effects

The problems described above tend to compound, aggravate and self-perpetuate. They cause a situation where the flow processes in construction are unnecessarily fragmented, complex, intransparent and variable. This has consequences for the behavior and mind set of all parties in construction. In project control, “firefighting” ongoing or looming crises consumes management resources and attention so totally, that there is little room for planning, let alone improvement activities : “ Managers are too occupied with the complexities involved in getting the work done to think about, much less to carry out, organized programs [for productivity improvement]” (Oglesby & al. 1989).

In fact, the whole construction culture is characterized by this short term, action oriented behavior: “Firefighters get the laurels” (Ballard 1989). Rewards for improvement based on proactive and systematic action are not clear.

Developments in construction technology and market demands, like the increasing variety of materials and components, and requirements for shorter project duration, tend further to aggravate the inherent problems in construction processes.

4.3 Waste and value loss in construction

If the flow aspects in construction have been historically neglected, it logically follows that current construction would demonstrate a significant amount of waste, loss of value, and non value-adding activities. Thus, it is appropriate to check whether the existing information supports this hypothesis.

As far as it is known, there has never been any systematic attempt to observe all wastes in a construction process. However, partial studies from various countries can be used to indicate the order of magnitude of non value-adding activities in construction. However, the figures presented tend to be conservative, because the motivation to estimate and share them is greatest in leading companies, which may be near the best practice. Furthermore, even an energetic effort to observe all quality problems does not reach all of them. A wide variation due to local conditions, project types, construction methods etc. may also be anticipated.

Quality costs are perhaps the best researched area. In numerous studies from different countries, the cost of poor quality (non conformance), as measured on site, has turned out to be 10 - 20 % of total project costs (Cnudde 1991). In a very detailed Swedish study on a design-construct project, the costs of quality failures for a construction company were found to be 6 % (Hammarlund & Josephson 1991). In an American study of several industrial projects, deviation costs averaged 12.4 % of the total installed project cost; however, “this value is only the tip of the iceberg” (Burati & al. 1992).

The causes of these quality problems are attributed to

- design 78 % (Burati & al. 1992), 23 % (Hammarlund & Josephson 1991) and 46 % in a Belgian study (Cnudde 1991)
- construction 17 %, 55 % and 22 %, respectively
- material supply 20 % and 15 % (in the last two cited studies).

The loss of value (understood as exceptional maintenance) to owners during facility use has also been studied in several countries. In Sweden and Germany these external quality costs are estimated to be 3 % of the value of annual construction production (Hammarlund & Josephson 1991). When the average costs for exceptional maintenance are traced back to the time of the actual construction, the loss of value is found to be 4 % of the production cost, in the case of Sweden. 51 % of these costs are associated with design problems, 36 % with construction problems and 9 % with use problems. As for the other aspect of loss of value, failure to attain the best possible performance, we have little data.

Thus, quality problems are considerable in all phases of construction. Especially, design is often the source of quality problems: sometimes it seems that the wastes and losses caused by design are larger than the cost of design itself. Even if there is a lack of data on the internal waste in design, it can be inferred that a substantial share of design time is consumed by redoing or waiting for information and instructions.

Constructability is the capability of a design to be constructed (The Construction Management Committee 1991). Constructability of a design depends on the consideration of construction constraints and possibilities. Projects where constructability has been specifically addressed have reported 6 - 10 % savings of construction costs (Constructability 1986).

In a Business Roundtable study, materials management was found to be generally neglected (referred by Oglesby & al. (1989)). It has been estimated that 10 - 12 % savings in labor costs could be produced by materials-management systems (Bell & Stukhart 1986). Further, a reduction of the bulk material surplus from 5 - 10 % to 1 - 3 % would result. Savings of 10 % in materials costs are reported from vendor cooperation in streamlining the material flow (Asplund 1991). According to a Swedish study, excess consumption of materials on site (scrap, wastage and surplus) is on average 10 %, varying in the range of 5 - 30 % for different materials (Bättre materialhandling på bygget 1990).

As for work flow processes, the average share of working time used in value-adding activities is estimated to be 36 % (Oglesby & al. 1989) or 31.9 % (Levy 1990) in the United States. There are similar figures from other countries (for example, National Contractors Group 1990).

Another waste factor is lack of safety. In the United States, safety-related costs are estimated to be 6 percent of total project costs (Levitt & Samelson 1988).

Thus, there is strong empirical evidence showing that a considerable amount of waste and loss of value exists in construction[2]. A large part of this waste has been hidden, and it has not been perceived as actionable.

4.4 Detrimental impact on development efforts

The many problems of construction have led to various development efforts. However, deficient conceptualization may lead to suboptimal or counterproductive conclusions and actions. Industrialization and computer integrated construction are examples of efforts that initially have been based on the traditional conceptualization, but the neglect of flow processes seems to have become a barrier for progress.

4.4.1 Industrialization

The traditional goals of industrialization of construction (Warszawski 1990) match well with the goals of process improvement: industrialized construction simplifies site processes and provides benefits of repetition. However, the total process of construction tends to become more complex and vulnerable due to using two production locations (factory and site) and increased co-ordination needs.

In industrialization, process improvement has not been taken as a goal in itself. This has been detrimental because industrialized construction requires considerably better controlled processes than on-site construction. For example, requirements for dimensional accuracy as well as co-operation within the design and planning processes are more important in industrialized construction.

Thus, it seems to be a plausible hypothesis that poorly controlled design, prefabrication, and site processes have often consumed the theoretical benefits to be gained from industrialization.

4.4.2 Computer integrated construction

In recent years, computer integration has become a major development target in construction. The basic idea in the pursuit of computer integrated construction (CIC) is to facilitate communication of data, knowledge and design solutions between project participants. Related development efforts have focused primarily on technical issues: the data structure of the constructed product and, to a lesser extent, of the production process.

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[2]Of course, this is not surprising in view of the widely held opinions on construction. Schonberger (1990) comments that construction does not fit the usual categories of industries:

> "One industry, construction, is so fouled up as to be in a class by itself. Delay, lack of coordination, and mishaps (especially return trips from the site to get something forgotten) are normal, everyday events for the average company."

The original basis of CIC is activity-oriented. After observing a task poorly carried out, namely data communication, it is suggested that this task be computerized[3]. However, here we again confront the myopic view of improving tasks or activities in isolation from the flow.

In fact, there is increasing empiric evidence that flow process problems, like excessive fragmentation and segmentation, effectively hamper the implementation of integration technology (Liker & al. 1992, Anon. 1991). Thus, a neglect of process improvement is a barrier to technical integration[4].

4.5 Conclusions

The situation in construction may be characterized as follows:

- the conceptual basis of construction engineering and management is conversion oriented (though the term activity is most commonly used)
- the managerial methods deteriorate flows by violating principles of flow process design and improvement
- as a consequence, there is considerable waste in construction
- waste is invisible in total terms, and it is considered to be inactionable
- improvement efforts have been hampered by their neglect of flow aspects.

However, this is the very situation faced by manufacturing. The following characterization by Plossl (1991) could as well describe construction:

> "The consensus of practically all people in manufacturing, until very recently, was that the problems experienced daily were inevitable and that it was necessary to learn to live with them. The real heroes were those individuals who could solve problems shortly after they arose, regardless of how they solved them."

Thus, following the lead of manufacturing, the next task is to reconceptualize construction as flows. The starting point for improving construction is to change the way of thinking, rather than seeking isolated solutions to the various problems at hand.

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[3] For more detailed treatment, see Dupagne (1991).

[4] Recently, these issues have been increasingly addressed in the framework of organizational integration.

5 Construction as flow

Construction should be viewed as composed of flow processes. In the following, a view of the construction project based on flows and their associated wastes and values is given. Measuring flows in construction is then commented upon.

The most acute flow problems of construction are caused either by traditional design, production and organization concepts, or the peculiarities of construction. Thus, these issues necessitate special consideration. After examining solutions to the problems caused by the traditional managerial principles, the impact of construction peculiarities on process control and improvement is analyzed.

Taking flows as the unit of analysis in construction leads to deep changes of concepts and emphasis. This initial interpretation will only scratch the surface.

5.1 Flow processes in construction

There are two main processes in a construction project:

- *Design process*: is a stagewise refinement of specifications[1] where vague needs and wishes are transformed into requirements, then via a varying number of steps, to detailed designs. Simultaneously, this is a process of problem detection and solving. It can be further divided into individual subprocesses and supporting processes.
- *Construction process*: is composed of two different types of flows:
    - Material process consisting of the flows of material to the site, including processing and assembling on site.
    - Work processes of construction teams. The temporal and spatial flows of construction teams on site are often closely associated with the material processes.

Other processes, which control or support the main processes, include:

- Project management process by the owner.
- Design management process by the engineering or design project manager.
- Construction management process, where the detailed design is transformed into a construction/fabrication plan and into day-to-day coordination and control of processes on site or in a factory.

The processes may be characterized by their cost, duration and the value for the customer. The value consists of two components: product performance and freedom from defects (conformance to specification). Value has to be evaluated from the perspective of the next customer and the final customer. Cost and duration depend on the efficiency of value-adding activities and the amount of non value-adding activities.

Let us consider, in a simplified manner, design and construction from the point of view of value and cost. Time (duration) could be analyzed in a similar manner to cost. Let us assume that efficiency of value-adding activities is the same in organizations considered[2].

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1 For more detailed discussion, see (Juran 1988, Webster 1991).

2 This is not a too rigorous assumption; especially in site construction, where equipment renting is common, all competitors have access to the same assortment of technology.

The cost of design is made up of costs of value-adding activities and waste. The waste in the design process is formed by

- rework (due to design errors detected during design)
- non value-adding activities in information and work flows

The design process has two customers: the construction process and the client. The value for the client is determined by

- how well the implicit and explicit requirements have been converted into a design solution
- the level of optimization achieved
- the impact of design errors that are discovered during start-up and use.

The value of the design for the construction process is determined by

- the degree to which requirements and constraints of the construction process have been taken into account
- the impact of design errors that are detected during construction

The inherent waste in construction is created by

- rework due to design or construction errors
- non value-adding activities in the material and work flows, such as waiting, moving, inspecting, duplicated activities, and accidents

The construction process has as its customer the client. The value of the construction to the client is determined by

- the degree of freedom of defects discovered during start-up and use.

The primary focus in design is thus on minimizing value loss, whereas in construction it is on minimizing waste. It has to be stressed that both wastes and value losses are real and considerable, as described above.

Due to the one-of-a-kind project character of construction, it is necessary to have two time frames for analysis: a project time frame and a longer time frame. From the viewpoint of a particular one-of-a-kind project, the goal is to attain the level of cost and value of the best existing practice (Figure 6). For the project, flows from different companies are combined, often only for one run. Consequently it is important to assure the process capability of companies to be selected for the project.

From the longer term point of view, the organizations in construction have to improve the processes continuously in order to meet and beat the best practice. However, even the best practice has an ample reserve of improvement potential, and the efficiency of the best practice is - or at least should be - continuously moving (Figure 7).

The above discussion, with its emphasis on process improvement, down plays the potential of innovation to improve conversion processes. However, innovation is often closely related to process improvement: new equipment may ensure less variability, new material may make a simplified process possible.

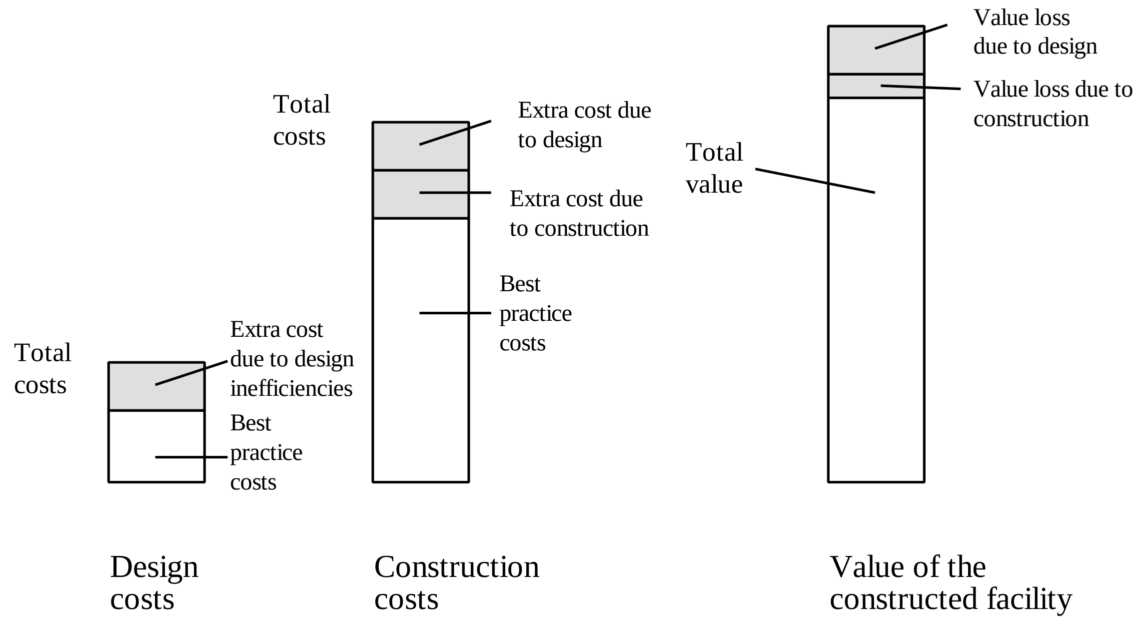

Figure 6. The decision situation from the point of view of the client. Note that design and construction duration can be analyzed similarly to costs.

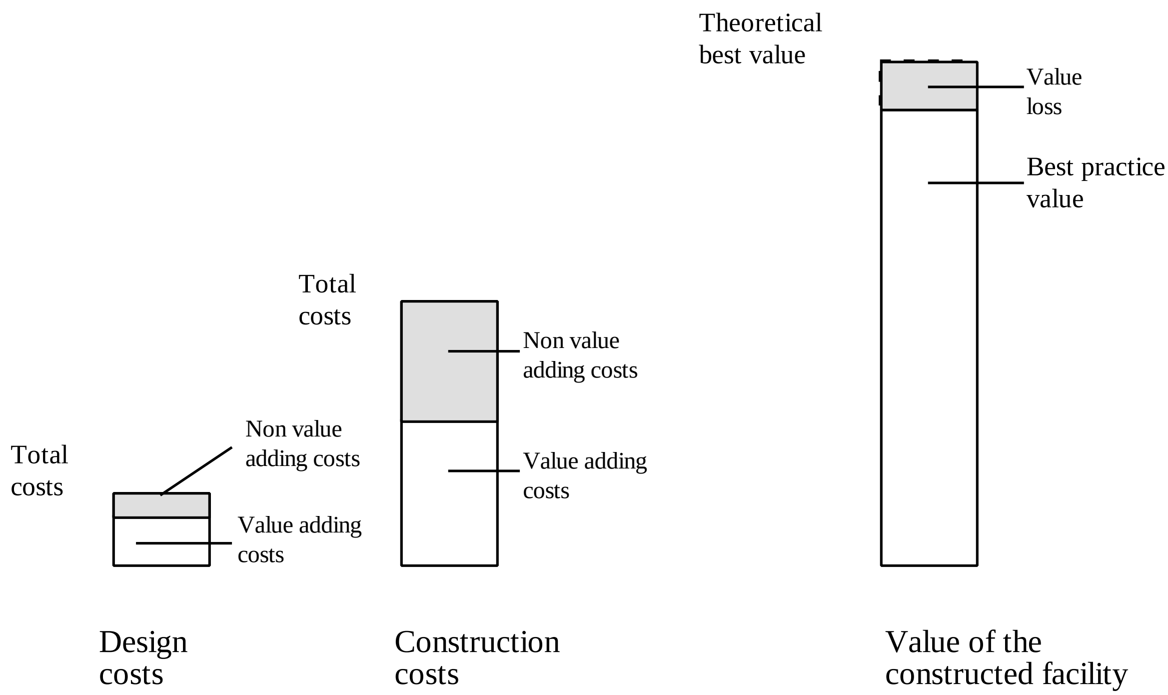

Figure 7. The process improvement potential for the best practice organizations. Again, time should be analyzed in a parallel fashion to costs.

Compare this analysis with the conventional discussion on the diminishing degree of influence of decisions on project cost during the progress of the project (for example, Barrie & Paulson 1984). It is acknowledged in this analysis that

- time and value, in addition to costs, are influenced by decisions in the project,

- influencing costs, time and value within the project is equivalent to manipulating flow characteristics,
- cost, time and value are also dependent on the long term efforts of participating organizations for continuous improvement.

5.2 Measures for construction

It is evident that the conventional measures of construction, which most often focus on cost or productivity, fail to make waste visible and to stimulate continuous improvement, as argued in Section 3.6. New measures are needed. Clearly, this theme is an open invitation to research and development[3].

> Three of the visited companies were in the process of developing or already using new measures and measurements systems in connection to continuous improvement efforts[4].

The following discussion is confined to illustrating new measures and to commenting on difficulties in establishing suitable measures for comparisons and benchmarking.

Measurement data are needed for two purposes: for driving internal improvement in the organization, and for targeting and comparison across projects and organizations. For organizations permanently participating in construction, both sets of measures are important. For a one-time owner, the latter type of performance data is of interest.

In the following, construction related measures are illustrated, based on the requirements presented in section 3.6:

- Waste: Such issues as number of defects, rework, number of design errors and omissions, number of change orders, safety costs, excess consumption of materials and the percentage of non value-adding time of the total cycle time for a particular work or material flow may be addressed.
- Value: The value of the output to the internal or external customer often has to be evaluated subjectively. For example, an aggregate measure for quality of industrial plants, based on subjective views, has been developed in a current study at CIFE (Fergusson & Teicholz 1992).
- Cycle time: The cycle times of main processes and subprocesses are powerful measures[5].
- Variability: Any deviations from the target can be addressed, like in schedule performance (percent of activities executed as planned).

There are three special problems encountered in developing measures for construction:

- Uniqueness of projects, related lack of repetition, and environmental uncertainty, which—at first sight—might make it difficult to compare between projects or organizations.
- Difficulty of data collection on site.
- Varying definitions and procedures for data collection.

When measurements are used internally, these problems can be overcome. Most organizations carry out roughly comparable projects, and data collection methods can be standardized inside the organizations. Also, it might be possible to measure uniqueness,

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3 Construction Industry Institute's Quality Performance Task Force is currently in the process of analyzing and evaluating measures used in design and construction.

4 This format is used to present anecdotal evidence from the companies visited by the author.

5 For discussion on time based competition in construction, see (Puyana-Camargo 1992).

complexity and uncertainty and to link efficiency and effectiveness targets to the degree of difficulty met.

As for measurement data used for comparison and targeting, the problems stated above are more severe. However, they may be solved by focusing on rates of improvement rather than on absolute values. This has other benefits as well:

- Differences in definition and data collection are to a great extent filtered away.
- Differences in project complexity, uncertainty, etc. between various companies are heavily reflected in the absolute values; however, it is reasonable that a logarithmic measure, like halving time, is comparable.
- Overall rate of improvement is the single most important measure in the long term.
- Halving time or percent change per year are simple and easy to understand.

As observed in benchmarking practice, information on rates of improvement, to be operational, should be accompanied by information about means for triggering that improvement .

In spite of all difficulties in finding commensurate data, an important measure for comparison and targeting is surely the world class level, that is, the absolute value of achievement of the best companies in the world. However, for targeting, it is useful to know the time it will take to reach this level, which is reflected in the rate of improvement, discussed above.

The industry average (or median) level of a performance measure is interesting, but potentially counterproductive. It tends to produce complacency in those companies better than average. For those companies worse than average, the target implicitly pinpointed by this benchmark is the average.

5.3 Overcoming flow problems caused by conventional managerial concepts

As stated in the previous chapter, the traditional managerial concepts have not only ignored but actively deteriorated flows of construction. Thus, it is of prime importance to introduce alternative methods conducive to flow improvement. Such methods have already been developed to varying degrees. Not unexpectedly, they try to implement those flow design and improvement principles which are violated by the managerial method in question.

It should be noted that the introduction of these alternative methods is only the start of process improvement. Other improvement actions will build on that foundation.

5.3.1 Alternatives to sequential mode of project realization

In manufacturing, the problems caused by the sequential method of product development have been addressed by the notion of concurrent engineering. To some extent, corresponding solutions have been developed and introduced in construction.

In general, the solutions have aimed at reduced cycle time, better consideration of the next stages, and complete processes as the focus of control. These are exactly the principles that are violated in the sequential method.

The term concurrent (or simultaneous) engineering (Barkan 1991) has been coined to refer to an improved design process, characterized by a rigorous upfront requirements analysis, incorporating the constraints of subsequent phases into the conceptual phase, and tightening change control towards the end of the design process. In comparison to the traditional sequential design process, iteration cycles are transferred to the earlier phases through cross-functional teamwork. Also overlapping of phases is used; however, intense information exchange is required. Compression of the design time, increase of the number of iterations and reduction of the number of change orders are three major objectives of concurrent engineering.

In construction, various partial solutions have been implemented for remedying the evident problems of the traditional approach. Most solutions concern organizational rethinking. For example, in design-build contracts, the contractor gains more influence in design solutions. In solutions involving construction management, an additional party is recruited for taking care of the flows.

Performance specification refers to a structured design procedure, where the requirements are made explicit, so that firms can offer their own technical solutions corresponding to the required performances (Louwe & van Eck 1992). The technical part of the design is thus transferred to parties which earlier were responsible only for execution. In conventional building design practice, functional performances often are not handled very explicitly, but rather iteratively during the stagewise development of the design solution and by soliciting client reactions to it. Performance specification endeavors to advance both the optimality of a particular project and the rate of innovation in general by involved parties. Concurrent engineering is facilitated by this structured approach.

Another area having been developed as a reaction to the traditional approach is systematization of constructability knowledge (The Construction Management Committee 1991).

5.3.2 Improving quality

At the risk of oversimplification, there are three recommendations presented in the extensive body of quality literature to the quality problem:

- design and improve processes to have low variability
- establish means for rapid detection and correction of any defect or deviation
- improve the mechanism by which specifications are defined for each conversion activity.

These correspond to the flow design and improvement principles concerning variability, cycle time and customer requirements. Various quality goals reflecting these recommendations have been increasingly accepted and implemented in construction during the last five years. Because this area is rather well understood, it is not discussed in more detail.

5.3.3 Non-segmented control

The basic solution is, of course, to focus control on complete flow processes. Usually this means that flows are the basis for organization, rather than specialties or functions as in the hierarchical organization. For example, a component manufacturer should be responsible for the whole material chain, including the installation on site. This will facilitate the application of other solutions developed in the JIT-approach to material flows, like smaller batch size and continuous flow, which contribute to cycle time reduction.

However, solutions which overcome the problems of segmented control in construction are still scarce and tentative. Experimentation, development and research are needed.

5.3.4 From network planning to flow planning

In both work planning and materials management, the emphasis should change to complete flow processes rather than discrete activities. Birrell (1980) has described a heuristic method for flow oriented work planning. Recently, there have been attempts to integrate flow planning with network methods (Huang, Ibbs & Yamazaki 1992, Osawa 1990).

This field will provide fruitful opportunities for research and development, especially with respect to computerized tools to accomplish flow planning.

5.4 Overcoming flow problems caused by the peculiarities of construction

5.4.1 Construction peculiarities

Because of its peculiarities, the construction industry is often seen in a class of its own, different from manufacturing. These peculiarities are often presented as reasons - or excuses - when well-established and useful procedures from manufacturing are not implemented in construction.

Construction peculiarities refer especially to following features (Tatum & Nam 1988, Warszawski 1990):

- One-of-a-kind nature of projects
- Site production
- Temporary multiorganization
- Regulatory intervention

Other construction attributes, such as durability and costliness, are not considered relevant in this context. Also construction may be characterized as complex and uncertain. These two features, which are shared by many other industries, are treated as resultant process features rather than as primary peculiarities.

Indeed, these peculiarities may prevent the attainment of flows as efficient as those in stationary manufacturing. However, the general principles for flow design and improvement apply for construction flows in spite of these peculiarities: **construction flows can be improved**. But certainly it is a core issue to understand these peculiarities and to be able to avoid or alleviate their detrimental effects.

In the following, the process control and improvement problems caused by the peculiarities are analyzed. Solutions, both well-known and those suggested by the new production philosophy, are presented.

5.4.2 One of a kind product

Characterization

The one-of-a-kind nature of each building or facility is caused by differing needs and priorities of the client, by differing sites and surroundings, and by differing views of designers on the best design solutions (Warszawski 1990). This one-of-a-kind nature, which varies along a continuum, covers most often the overall form of the building or facility. The materials, components and skills needed are usually the same or similar. From the point of view of contractors and design offices, there is continuity and repetition:

roughly similar projects and tasks recur[6]. Thus, it has to be stressed that the problems associated with one-of-kindness affect only certain processes in any project.

Usually there is significant input into the design process by the client, who is often a one-time participant in the process and thus does not have the benefit of learning from prior project cycles.

Problems of process control and improvement

There are several major problems of process control and improvement related to one-of-a-kind production.

No complete feedback cycles are possible because the product is costly: what would be a prototype to be debugged and developed further in manufacturing, is the end product in construction.

The input by a lay client tends to be incoherent and unorganized, often activated by exposure to detailed design solutions. Such corrections of omissions in later phases of the project disrupts the otherwise smooth flow of activities.

The general problem in the production of one-of-a-kind buildings is that the configuration of the flows has to be specifically designed. There are activities in the flow that are difficult to control because of novelty. In one-of-a-kind tasks, figuring out the respective goals and constraints is error-prone and time-consuming; the benefits of learning and continuous improvement are not at hand. Also, the coordination of the project is hampered by duration uncertainty and unknown characteristics of one-of-a-kind activities.

From the point of view of process improvement, measuring is a concern: one-of-a-kind projects are not viewed as comparable, and incremental progress from project to project has been difficult to perceive.

To sum up, the following principles for flow design and improvement are difficult to realize: reduction of variability, continuous improvement, enhancement of transparency, compression of (learning) cycle time. The solutions presented below attempt to implement these principles.

Solutions

The first, and most basic approach to the one-of-a-kind nature of construction is to eliminate those unique solutions in a project not absolutely necessary due to client or site idiosyncrasies or artistic expression of the designer. In this way, proven standard work flows and associated components, skills, etc. can be used. Closed or open industrialized building systems provide solutions to be considered (Warszawski 1990). Recently, construction companies have begun to offer concept buildings (office buildings, schools, day nurseries, etc.), which are pre-engineered solutions that can be adapted to different needs.

The lack of repetition and thus feedback cycles can be remedied by creating artificial feedback cycles (Chew 1991 & al. 1991): simulation in its various forms, physical models,

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[6] It is often argued that construction projects are unique, and especially different from manufacturing in this aspect. However, claims of uniqueness of particular plants abound in manufacturing as well (Plossl 1991, Chew & al. 1990). It seems that there is a psychological urge to see one's own system as unique.

or learning from corresponding earlier projects. Accomplishing novel tasks on site can be facilitated by planning and training with mock-up models. Interestingly, it is a practice in Japan to publish solutions used in unique projects in scholarly journals.

The management of the client requirement formulation process is another need. Systematic investigation of requirements and client involvement in conceptual design produce upfront a requirements list, which facilitates progress in subsequent phases.

With regard to site activities, the problems of one-of-a-kind tasks can be remedied with high quality documents and clear instructions. Costly activities of sufficient duration warrant careful methods study and improvement. Continuous planning[7] will prevent non value-added time from inflating on site.

In general, the problems of one-of-a-kind nature are compounded by the two next problems: production on site and and temporary organization[8].

5.4.3 Site production

Characterization

Construction production is typically carried out at the final site of the constructed product, often inside the evolving product

Problems of process control and improvement

There are four major process control and improvement problems with respect to site production:

- Variability problems: There is usually little protection against elements or intrusion, rendering operations prone to interruptions. Permanent safety fixtures cannot be used in the evolving environment. Local material and labor input often has to be used, potentially adding to uncertainty. Other areas of uncertainty include site geology and additional environmental factors.
- Complexity problems: The spatial flow of work stations (teams) has to be coordinated (in contrast to a factory, where only material flow through work stations is planned).
- Transparency problem: The working environment is continuously evolving, making layout planning laborious. Due to the evolving environment, visual controls are difficult to implement.
- Benchmarking problem: Site production is by nature decentralized production, with associated problems of transferring improvement[9].

Solutions

The most basic solution to alleviate the site problems is to configure the material flows so that a minimum number of activities are carried out on site. The rationale of prefabrication, modularization and preassembly is partly based on this principle. Likewise, in more site

[7] The observations of Laufer (1991) on coping with uncertainty in planning are relevant here.

[8] The methods and concepts of schedule compression (Construction Industry Institute 1988) address all these problems.

[9] In manufacturing, there are also great difficulties in transfering improvement from plant to plant within one company (Chew & al. 1990). The performance differences may as great as 2:1 (after controlling for other differences in age, technology, etc.) between the best and the worst plant.

oriented construction some activities such as inspection, storage, sorting etc., can be pushed upstream in the material flow.

The next solution is to arrange necessary protection by means of temporary enclosures, if feasible and cost-effective.

Site production sets high demands on planning because of its uncertainty, changing work environment and numerous coordination needs. Planning of material and work flows is time consuming, and in practice it is poorly executed. Research shows that more meticulous planning, than currently is usual, is beneficial[10]. The difficulty of spatially coordinating the work flow can be alleviated by establishing multi-skilled work groups, which coordinate through mutual adjustment.

In practice, site operations are rather poorly systematized; only a handful of companies have standard methods for various site operations (Oglesby & al. 1988). However, only through standard methods can the variability be decreased and the rapid diffusion of improvements be ensured.

The general JIT-technique of smaller batches may also be beneficial for reducing variability and inducing improvement on site. Indeed, there are several work planning methods in Japan which aim at this (Takada 1991). Typically, each floor is divided into multiple zones, and repeated cycle operations are allotted to various teams.

5.4.4 Temporary multiorganization

Characterization

A construction project organization is usually a temporary organization designed and assembled for the purpose of the particular project. It is made up by different companies and practices, which have not necessarily worked together before, and which are tied to the project by means of varying contractual arrangements. This is a multiorganization. Its temporary nature extends to the work force, which may be employed for a particular project, rather than permanently.

However, these characteristics are often not caused by objective conditions, but rather are a result of managerial policy aimed at sequential execution and shopping out the various parts of the building at apparently lowest cost.

Problems of process control and improvement

The problems for process control and improvement are related to the principles concerning continuous improvement, variability and complete processes as the focus of control. In practice there are problems of:

- communicating data, knowledge and design solutions across organizational borders
- stimulating and accumulating improvement in processes which cross organizational borders
- achieving goal congruity across the project organization
- stimulating and accumulating improvement inside an organization with a transient workforce.

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10 See (Laufer & Tucker 1987, 1988) and (Shohat & Laufer 1991).

Solutions

The basic problem of communicating data, knowledge and design solutions over organizational borders can be addressed by

- procuring from a network of organizations with long term cooperation
- team building during the project
- clear definition (general or project wise) of roles of each participant and mutual interfaces (essentially a Project Quality Plan)
- decoupling of work packages (as in the French sequential procedure, to be explained in section 6.1.4).

Improvement across the conventional organizational borders can be stimulated by long term relationships or partnerships between

- contractor and subcontractor
- owner and engineering firm
- engineering firm and vendor.

Goal congruence may be enhanced with facility procurement solutions, like the construct and operate procurement method, becoming common for new electrical power generation plants in the U.S.

5.4.5 Intervention of regulatory authorities

Characterization

The design solution and many work phases in a construction project are subject to checking and approval by regulatory authorities.

Problems of process control and improvement

Authority intervention causes uncertainty and constraints to the process. Getting an approval for a design solution is often unpredictable. Checking by authorities during the construction process can cause delays. Codes may be barriers for innovation, if they rigidly require a procedure, rather than a performance.

These principles of (regulatory) cycle time, variability and continuous improvement need to be applied to these problems.

Solutions

Inspection activities should be included as part of the flow process of production, subject to improvement by application of the eleven principles. The approval process can usually be simplified and speeded (as realized for example, in Norway). Authority checking during execution can be substituted with self-checking by the executing firm, provided it has a necessary quality control system. The building codes can be converted to be performance based (as has already happened in the Netherlands) (Louwe & van Eck 1991).

5.4.6 Discussion

The problems associated with the peculiarities of construction are well-known in practice, and various countermeasures have been developed and implemented, as presented above and summarized in Table 4. These peculiarities tend to hamper control and improvement by violating principles of flow design and improvement, and increasing the share of non value-adding activities. However, by implementing structural solutions these peculiarities can be avoided or at least minimized. Various operational solutions alleviate control problems and improvement problems respectively.

In any case, the general principles for flow design, control and improvement apply. Construction peculiarities cannot serve as an excuse for neglect of process improvement.

These solutions will be refined and novel solutions will surely emerge through practical improvement efforts.

Table 4. Overview on problems related to construction peculiarities and corresponding solutions. Process control refers to the management of a project, process improvement to the development efforts of the permanent organizations in construction (designing, manufacturing of materials and components, contracting).

Peculiarity	**Process control problems**	**Process improvement problems**	**Structural solutions**	**Operational solutions for control**	**Operational solutions for improvement**
One-of-a-kind	No prototype cycles Unsystematic client input Coordination of uncertain activities	One-of-a-kind processes do not repeat, thus long term improvement questionable	Minimize the one-of-a-kind content in the project	Upfront requirements analysis Set up artificial cycles Buffer uncertain tasks	Enhance flexibility of products and services to cover a wider variety of needs Accumulate feedback information from earlier projects
Site production	External uncertainties: weather etc. Internal uncertainties and complexities: flow inter-dependencies, changing layout, variability of productivity of manual work	Difficulty of transferring improvement across sites solely in procedures and skills	Minimize the activities on site in any material flow	Use enclosures etc. for eliminating external uncertainty Detailed and continuous planning Multi-skilled work teams	Enhance planning and risk analysis capability Systematized work procedures
Temporary organization	Internal uncertainties: exchange of information across organization borders (flow disconnects)	Difficulty of stimulating and accumulating improvement across organization borders	Minimize temporary organizational interfaces (interdependen-cies)	Team building during the project	Integrate flows through partnerships
Regulatory intervention	External uncertainty: approval delay			Compression of approval cycle Self-inspection	

5.5 Conclusions

The view of a construction project based on flow processes leads to theoretical understanding and to practical guidelines for improvement.

Theoretically, the causes for the chronic problems in construction are clarified by pinpointing the generic process problems from which they originate. The problems of construction fall into two different clusters of causes. The first is the application of traditional design, production and organization concepts, which in the course of time have become inefficient. Secondly, construction has peculiarities which have not been adequately handled. These issues necessitate special consideration in regard to avoiding or alleviating their detrimental impact on process control and improvement.

With respect to practical application, this approach provides for evaluation of existing flows (by means of measures like those presented above), identification of improvement potential, and guidance of operational improvement action. Thus, persistent problems may be identified and cured and processes generally improved in a long term effort by committed companies in the construction sector. These issues will be discussed in more depth in the following chapter.

6 Implementation of the new production philosophy in construction

6.1 Present status of implementation: experiences and barriers

6.1.1 Initial implementation limited by barriers

In the construction industry, interest in the new production philosophy has grown rather slowly. Three major thrusts of implementation can be discerned[1]:

- The new approach, in its JIT-oriented form, has been used in manufacturing oriented parts of the construction industry, like in the production of windows, elevators and prefabricated housing.
- In mainstream construction, quality-based efforts have been launched by a growing number of organizations; this includes TQM but also such developments as partnering, team building, continuous improvement and constructability.
- In several countries, there are initiatives to change the project organization and procurement methods so that obstacles for process improvement will be eliminated.

All in all, however, the overall adoption of the new philosophy in construction is rather limited in scope and methods. What are the reasons for this reluctance?

The following barriers to the implementation of these ideas in construction can be observed:

- Cases and concepts presented to illustrate the new approach (for example batch size reduction, work-in-progress reduction, set-up time reduction, layout simplification) are usually from the realm of mechanical fabrication and assembly, so are often not easy to internalize and generalize from the point of view of other industries, as pointed out by Baudin (1990). It has not been clear whether the new approach is at all feasible in an activity so different from manufacturing.
- The idiosyncrasies of construction, like unique, one-of-a-kind products, site production, temporary project organizations and regulatory intervention necessitate an industry-specific interpretation of the general principles of the new production philosophy, which currently exist only in outline.
- International competition, which in car manufacturing is a major influencing factor, is relatively sparse in domestic construction of major industrialized countries.
- Lagging response by academic institutions: the new philosophy is not acknowledged in educational curricula or research programs. The nature of the new production philosophy as an engineering based, rather than as a science based endeavor is certainly a major cause for this.

However, all of these barriers are temporary; they may retard and frustrate the diffusion but not thwart it.

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[1] One could argue that the Japanese construction industry is a fourth area, where many of the ideas of the new production philosophy have already been incrementally introduced. Bennett (1991) writes: “The Japanese building industry delivers reliable quality, on time, with a certainty not matched anywhere else in the world. This performance is the result of decades of steady development based on the principles of mass production: simplify, standardize and systematize.” Unfortunately, current Japanese practice could not be examined in this study in detail.

6.1.2 Construction subprocesses of manufacturing character

Currently some construction subproducts are produced in processes that possess a manufacturing character. The assembly of such components with the building frame usually represents a minor share of the total costs. Windows, doors, elevators, prefabricated concrete components, and prefabricated houses, are examples of this kind of manufactured product. (However, ceramic tiles or bricks, for example, even if produced in factories, are not in this group because a considerable part of the cost of the end product accrues on site.)

There are several notable examples of successful implementation of the new production philosophy to this kind of process. Schonberger (1990) reports on a Japanese factory producing prefabricated houses with a customer lead time of forty days (from order to completion on site), and production time (first to last operation) of one day. A Finnish window manufacturer provides delivery and installation of windows on site with a 15 minute accuracy (Koskela 1991). An American industrial door manufacturer has gained a considerable competitive benefit from JIT production and short cycle times (Stalk & Hout 1990).

In regard to quality management, clear progress has been made in many countries. Many supplying firms have acquired quality certification according to the ISO standard.

The application of the new production philosophy is least problematic in this part of the construction industry: the methods and techniques developed in manufacturing can be applied directly. However, except for quality management techniques, only a minor fraction of the factories and plants delivering to construction sites have begun to implement the new philosophy. It may be anticipated that this transformation will proceed rapidly after having gained initial momentum. Thus, industrialized construction might gain competitive benefits sooner than site construction.

6.1.3 Mainstream construction

Only the quality oriented approaches have been applied to any considerable extent in the mainstream construction world. The quality issues have received increasing attention since the beginning of the 1980's, and construction specific interpretations of the general quality methodologies have been published (for example, Shimizu 1979 and 1984, Cornick 1991, Burati 1992, Leach 1991). On the basis of the practical experiences of pioneering companies[2], the methods may be further refined.

> Three of the visited companies had recently launched formal TQM programs. The thrusts in those programs are:
>
> - definition and standardization of work processes (especially cross-functional) and appointment of process owners, responsible for maintenance and improvement of the respective process
> - establishment of teams for finding solutions to selected bottleneck problems
> - development of a measurement system to support and monitor process improvement.
>
> One company had explicitly adopted the goal of cycle time reduction, beyond the customary TQM emphasis on customer value and variability reduction.

While quality management has provided considerable direct benefits, it has also served as a starting point for process improvement. However, continued progress and widening of

[2] See the forthcoming CII report "Implementation Process for Improved Quality".

themes considered seems to be somewhat problematic. The basic problem is that quality management basically addresses only a partial (although important) set of wastes, namely defects and failures to consider customer requirements. The often somewhat rigid and dogmatic methodologies do not easily allow for a wider perspective. Another problem seems to be that quality management has often been introduced as a second management track, separate from the real management process. Sometimes the implementation of quality management is more related to marketing and image, say ISO certification or winning a national quality award, than to an urge for internal improvement.

Other process improvement principles are being used incidentally[3]. A French construction company has carried out a simplification campaign for streamlining administrative procedures. A British construction company has taken as its goal to be on-time, that is to reduce time variability in its processes. In a Swedish company, the reduction of cycle time for construction projects is being adopted as a goal.

However, the common problem of the majority of these efforts is that only a few process design and improvement principles are used. Thus, while quality management remains a useful and proven entry point to process improvement, there is a need to proceed to the application of all available principles of process design and improvement.

6.1.4 Industry wide initiatives

The traditional way of organizing construction has been found in many countries to hamper performance improvement and innovation. The idea of changing the organization in order to eliminate these obstacles has been the motivation of three initiatives aimed at industry wide changes in European countries:

- the sequential procedure in France
- the open building method in the Netherlands
- the new construction mode in Finland.

These methods have been developed primarily to advance innovation in construction, and they have not been based directly the new production philosophy. However, they have several implications regarding the new production philosophy. In the following, they are analyzed in more detail from that point of view.

The sequential procedure

The main idea of the sequential procedure[4] is to plan the site work as successive realizations of autonomous sequences. A sequence is defined in terms of regrouping of tasks by functions of the building, not in terms of traditional techniques or crafts. During a sequence a firm can operate without interferences because it is the only organization on site. After each sequence, there is a quality inspection and turn over of the works. The due dates of sequences are strictly controlled.

The sequential procedure follows closely, even if implicitly, the ideas of the new production philosophy. In the following, an interpretation of the methods and purposes of the sequential procedure, as presented in (Gilbert 1991, Lenne 1990, Cazabat & al. 1988, Bobroff & Campagnac 1987), is made from the point of view of applicable process improvement principles:

[3] Information is this paragraph is based on trade journals and oral communication.

[4] Note that “sequential procedure” has quite a different meaning than the term “sequential method of project organization” discussed earlier.

- Waste reduction. The goal is to reduce non value-added time due to excessive specialization: however, other waste components are not as explicitly attacked.
- Variability reduction. With several strict due dates and quality control points during the project, defects and problems do not easily migrate downstream. Preplanning is facilitated through reduced external uncertainty.
- Cycle time compression. Sequence cycle time (site time of each sequence) is compressed by utilizing more prefabrication and preassembly (of course, the total cycle time may be longer than in conventional construction due to preparation and prefabrication)
- Simplification. By establishing strictly sequential work packages, activity interdependencies are reduced and organization and planning of construction is thus simplified.
- Flexibility. Development of multi-skilled personnel is encouraged.
- Transparency. In the framework of each sequence, transparent material and information flows are easier to arrange.
- Control of complete processes. The sequences roughly correspond to separate material flow processes in construction. Processes are thus isolated from reciprocal disturbances. Development and optimization of the whole span of a process is encouraged.
- Continuous improvement. Long-term relationships are formed between firms for a particular sequence, which facilitates continuous improvement and innovation.

The sequential procedure has been tried out in a rather large number of projects, and the method has been further refined. It seems that this method is being adopted to use by owners, contractors and subcontractors in France; however, we do not know of actual data.

The open building system

The open building system is an integrated set of rules and agreements concerning the organization of design and building. The following features are stressed (Louwe & van Eck 1992, van der Werf 1990, van Randen 1990):

- performance concept
- modular coordination
- separation of the “support” (structural) and “infill” (interior work) parts of buildings
- specialized and multi-functional teams of craftsmen.

Especially the following process design and improvement principles are emphasized:

- Flexibility of design solutions in spite of relying on pre-engineered and prefabricated components.
- Simplification through modular coordination and standardization of interfaces between different building components.
- Control of complete processes, while allowing decision power for all concerned parties.
- Continuous improvement through project-independent product development by supplying companies.

This concept, having been developed over a period of 25 years, is now being introduced by a number of contractors and suppliers in the Netherlands.

The new construction mode

The goal of this new building process is to remove the causes of the current inherent problems in construction (Lahdenperä & Pajakkala 1992). It combines performance based design and final product (rather than input resource) oriented construction procurement . On the basis of performance requirements, supplier firms (or company groups) offer their pre-engineered (and often prefabricated) solutions for different subassemblies of the building.

A detailed procedure for implementing building projects by means of the new model has been prepared.

This model especially supports the following principles:

- Simplification: Through cutting off dependencies between subprojects, the effect of disturbances is diminished.
- Control of complete processes: Integration of design and construction is encouraged. Thus, learning through feedback is enhanced and product development is facilitated.
- Continuous improvement. Continuous collaboration is to be strengthened within firms and between firms.

This model has been developed toward the end of 1980's. The new building process has been the subject of heated discussion during the last two years or so in Finland. It is understood that it creates a lot of changes and it cannot be applied immediately as a whole. However, it has been applied to supplying subassemblies to buildings and also to a few whole buildings on an experimental basis.

Discussion

It is striking that these initiatives try to avoid or alleviate the problems caused by the peculiarities of construction:

- one-of-a-kind features are reduced through standardization, modular coordination and widened role of contractors and suppliers
- difficulties of site production are alleviated through increased prefabrication, temporal decoupling and through specialized or multi-functional teams
- the number of temporary linkages between organizations is reduced through encouragement of longer term strategic alliances.

While there are initial encouraging indications that these kinds of industry wide initiatives can eliminate barriers and stimulate improvement efforts, it must be noted that the actual implementation of process improvement has to be carried out by the organizations themselves. Here we can again consider the analogy provided by manufacturing. Elimination of construction peculiarities just brings construction to the same starting point as manufacturing. Unfortunately, a large amount of waste also exists in manufacturing before process improvement efforts begin.

Thus, we argue that process improvement initiated by the construction organizations is the primary driving force that should be strongly promoted in industry wide programs. Changes in project organizational systems will then be empowered by this momentum.

This kind of industry wide initiative might be especially beneficial to trigger improvement in medium and small construction companies . On the other hand, good results in process improvement have been gained by organizations not influenced by such initiatives. Also, the ideas presented here cannot easily be applied to all types of construction. All in all, empirical investigations are needed for clarifying the significance of these new organizational models for process improvement and innovation.

6.2 Implementation of process improvement by engineering and construction organizations

The inherent recommendation of the new philosophy to construction practitioners is clear: the share of non value-adding activities in all processes has to be systematically and persistently decreased. Increasing the efficiency of value-adding activities has to be continued in parallel.

The basic improvement guideline is thus: get started, define processes, measure them, locate and prioritize improvement potential, implement improvement and monitor progress! Several proven step-to-step methodologies that are useful even if most are narrow and not construction oriented (Imai 1986, Robson 1991, Plossl 1991, Kobayashi 1990, Harrington 1991, Kaydos 1991, Rummler & Brache 1991, Camp 1989, Moran & al. 1991, forthcoming CII report "Implementation Process for Improved Quality"). Earlier, some general remarks on the implementation of process improvement were presented in section 3.8. In the following, some issues that are likely to be encountered by construction organizations are commented upon briefly.

Getting started is often the toughest problem. It might be wise to adopt a proven, even if narrow, methodology for getting started. Total quality management often seems to be a good first step. On the other hand, there are experts who suggest an approach more focused on just starting to solve immediate problems and on learning-by-doing, rather than following specific implementation methodologies (Schaffer 1988).

Process definition and measurement is crucial. Work processes must first be made transparent by charting them. Next, the inherent waste in processes must be made visible through suitable measures, and targets and **monitoring** should be focused on it. As discussed earlier, a significant issue is to find measures which are project-independent. Even if measurements are not as straightforward as in manufacturing, they are not an insurmountable problem.

With regard to **improvement potential,** relations with other organizations might often be observed as sources of problems. However, for obvious reasons it is better to start with solving internal problems.

It is important to select and systematically use appropriate **principles, techniques and tools.** In manufacturing, a considerable number of specific principles and techniques have been developed for process improvement. To a perhaps considerable extent, they are also usable in construction. For example, the ideas concerning basic industrial housekeeping are directly applicable. Presumably construction-specific methods and techniques will emerge from practical work, as occurred in manufacturing.

Owners may be in a critical position for advancing flow process based thinking. Even if owners formally buy the output of all processes in a project, it is the capability of these processes which produce the success of the project, or the unanticipated problems which directly or indirectly cause losses to the owner. Thus, it is in the best interest of the owner to evaluate bidders on the basis of their process capabilities as well as cost. Owners are often in a unique position for complete process control and driving project-wide improvement.

Implementation of the new philosophy may be started with different levels of ambition. It is a multidimensional change and learning process, which can be launched by picking up just a few principles and techniques. If these are successfully institutionalized, adoption of further principles will be more easily accepted.

Given the relatively high share of waste in construction at present, it is evident that notable gains may be achieved in most organizations even by well directed initial efforts. Waiting for a consolidation of construction specific implementation methodology - which certainly will happen - is no excuse for sticking to the old routines.

6.3 Redefining major development efforts in construction

In many countries, major resources have been and are currently channeled to such development targets as industrialization, construction safety, computer integrated construction and construction automation. It is of prime importance that they are redefined in terms of the new conceptual basis.

6.3.1 Industrialization

Industrialization has been discussed in several contexts above. Here we summarize: Industrialization usually lengthens complete flow processes and makes them more complex than in conventional site construction (although flow processes on site are surely shortened and simplified). These processes must be improved in order to realize the potential that industrialization offers.

6.3.2 Safety

Safety is one of the chronic problems in construction. The new production philosophy can also contribute in this area.

Standardized, systematized and regularized production can be expected to lead to better safety as a side effect (Kobayashi 1990). There are several mechanisms for this:

- there is less material in the work area
- the workplace is orderly and clean
- the work flows are more systematized and transparent, so there is less confusion
- there are fewer disturbances (which, as it is known, are prone to cause accidents)
- there is less firefighting, and attention can thus be directed to careful planning and preparation of activities.

Viewed on the whole, a production process that progresses towards the goals of the new philosophy (less waste and variability) also improves its safety conditions. However, as far as is known, no statistical studies to verify this have yet been done.

> This view is reflected in the policy of one company to evaluate vendors on basis of their safety rate (among other criteria): "Without safety, a production process cannot produce high quality products."

Where the working environment is constantly changing, as it is in construction, safety is ultimately dependent on the avoidance of unsafe acts by workers (Nishigaki & al. 1992). In this respect, the principle: "Reduce the cycle time" should be applied. For example, the STOP-method (Safety Training Observation Program), developed by Dupont, aims at creating a procedure and atmosphere where all unsafe acts of workers, when observed by foremen, can be immediately noted and corrected. This rapid cycle of deviation detection and correction helps to realize a strict compliance to safety regulations in daily work.

One company visited by the author had achieved a dramatic improvement in safety through general improvement in engineering and planning processes, the implementation of STOP-method, and other safety measures. In a period of five years, the OSHA recordable accident rate was reduced by 94 %, and the lost time accident rate by 84 %.

Another company had also achieved a steady decrease in safety rates and costs mainly through systematic safety management and planning (including the STOP-method), and refined work planning methods.

Thus, it seems that major improvements of construction safety can be achieved through a three-pointed effort:

- improving engineering and construction planning processes to ensure safe, predictable work flow on site
- improving safety management and planning processes themselves to systematically consider hazards and their countermeasures
- instituting procedures which aim at minimizing unsafe acts.

Earlier approaches often viewed safety as a separate subject, which could be improved in isolation from other issues in construction. However, safety depends on the nature of material and work flows (and design and planning processes which support them), and must be continuously maintained and improved as an aspect of those processes.

6.3.3 Computer integrated construction

It was argued earlier that a neglect of process improvement has turned into a barrier to integration. As the previous analysis has shown, there are many different problems and corresponding solutions in construction. The concept of (technical) integration as general facilitation of information transfer by means of standardized data structures, to be implemented over a long time period, is unfocused and long term oriented in comparison to the immediate needs of the construction industry.

It has to be noted that technical integration provides only the infrastructure and potential for integration. Technical integration does not help much if the processes are otherwise not of high quality (errors, omissions, wait and inspection times, changes due to poor requirement analysis, long feedback cycles); probably it just adds to mess and complexity. This has been put succinctly with regard to CIM (Computer Integrated Manufacturing): “CIM acts as a magnifying glass. It makes the good system much better; it makes the poor system much worse” (Melnyk & Narasimhan 1992).

This analysis suggests that computer integration should not be a primary goal, but rather a means among others for attaining process improvement goals. The need for process improvement is often urgent and should be initiated with the means readily available (simultaneous engineering, work process definition and improvement, team approach, vendor quality programs) whereas many solutions for computer integration seem to take a longer time period to mature.

On the other hand, computerized systems often provide unique and superior solutions for process improvement (e.g. systematizing and error-proofing activities); however, without a drive for process improvement, such applications have often diffused slowly. The following are examples of this kind of solution:

- The transparency of a process may be augmented by computer visualization and simulation.
- Knowledge-based systems may be used for systematizing and standardizing operations and as error-proofing devices.

- Knowledge-based systems may be used for providing simplification advice (constructability).

Integration is thus not an intrinsic goal, but should rather be motivated by specific improvement needs of the construction process. Neither is CIC a construction theory; it cannot substitute for the substantial theories of production processes.

Thus, we should clarify the roles of process improvement and information technology (IT): process improvement is the primary phenomenon, which can be supported by information technology. More specifically, information technology may benefit process improvement in two ways:

1. Information technology may be used for automating specific conversions and subflows, leading to variability reduction, shortened cycle times, added transparency and other benefits.
2. Information technology may allow for process redesign, leading to radical process simplification.

In both cases, IT solutions should be tightly intertwined with and preceded[5] by organizational and other forms of process improvement[6]. Isolated process redesign through computerization, without a preceding culture of process improvement, is risky and difficult.

This fully conforms to the experiences gained in manufacturing in relation to CIM. The current guidelines heavily stress process improvement before automation (Table 5).

Table 5. Implementation steps for CIM systems (based on current practices of leading CIM users) (Melnyk & Narasimhan 1992).

1.	Focus: Manufacturing objectives derived from corporate objectives and strategy
2 a.	Simplification: Elimination of non value-adding activities or bottlenecks.
2 b.	Integration: Introduction and management of coordination and cooperation between activities and groups.
3.	Automation: Application of well-defined computer aided procedures to physical or information flows.

In the new approach, the integrated construction engineering process could be defined as follows: A process of well defined design subprocesses which cross over specialist functions and temporal phases in order to shorten iteration cycles and the whole design cycle and to move from local optima towards the global optimum.

5 Of course, this should not be taken categorically; in many tasks computers are used routinely, and process improvement and computerization can proceed in parallel.

6 This view is supported by a current CIFE study on the impact of integration on plant quality. The results, even if still subject to final evaluation, strongly indicate that organizational integration had a considerably larger positive impact on plant quality than technical integration in the projects studied.

Characteristic features of integrated construction engineering are the following (of course these are goals for process improvement in general):

- systematic, upfront requirements analysis
- explicit stagewise refinement of specifications
- maximizing the number of iterations
- assuring that no omissions and errors flow downstream
- minimizing non value-adding engineering activities.

6.3.4 Construction automation[7]

In contrast to computer integrated construction, where at least partial implementation has already occurred, construction automation is primarily a research and development theme in most countries. The primary question asked has been: To which construction tasks can robotics be applied? Answers to this question have been searched for in feasibility studies and construction robot prototypes.

How should we analyze construction automation from the point of view of the new production philosophy? Let us illuminate the relations between process improvement and automation in construction by means of the framework presented originally by Béranger (1987) in the context of manufacturing (Figure 8). Based on the principles for process design and improvement, the following statements will be elaborated and justified below:

- automation should be focused on value-adding activities (reduce non value-adding activities)
- process improvement should precede automation (balance flow improvement with conversion improvement)
- continuous improvement should be present in all stages (build continuous improvement into the process).

Automation should be primarily focused on value-adding activities

It is usually more effective to eliminate or reduce non value-adding activities than to automate them. If elimination is not possible, these activities should be automated with simple and inexpensive technology. However, it is usually not worthwhile to automate them with high technology, because a competitor might find the means to eliminate those activities. Thus, the automation efforts should be directed to value-adding activities.

Process improvement should precede automation

There are several specific arguments for focusing on process improvement before automation (Béranger 1987):

- simplified, streamlined and stable material and work flow contributes to the reliability of automated systems: automation hardware already has in itself a relatively high frequency of breakdowns;
- multi-skilled personnel are needed during the automation stage: the development of such personnel can be started during process improvement;
- process improvement and simplification decreases the difficulty and costs of automation and thus increases the profitability of automation; and
- process improvement can be started immediately with little cost, whereas automation can be a long, and expensive project.

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[7] The discussion is based on (Koskela 1992).

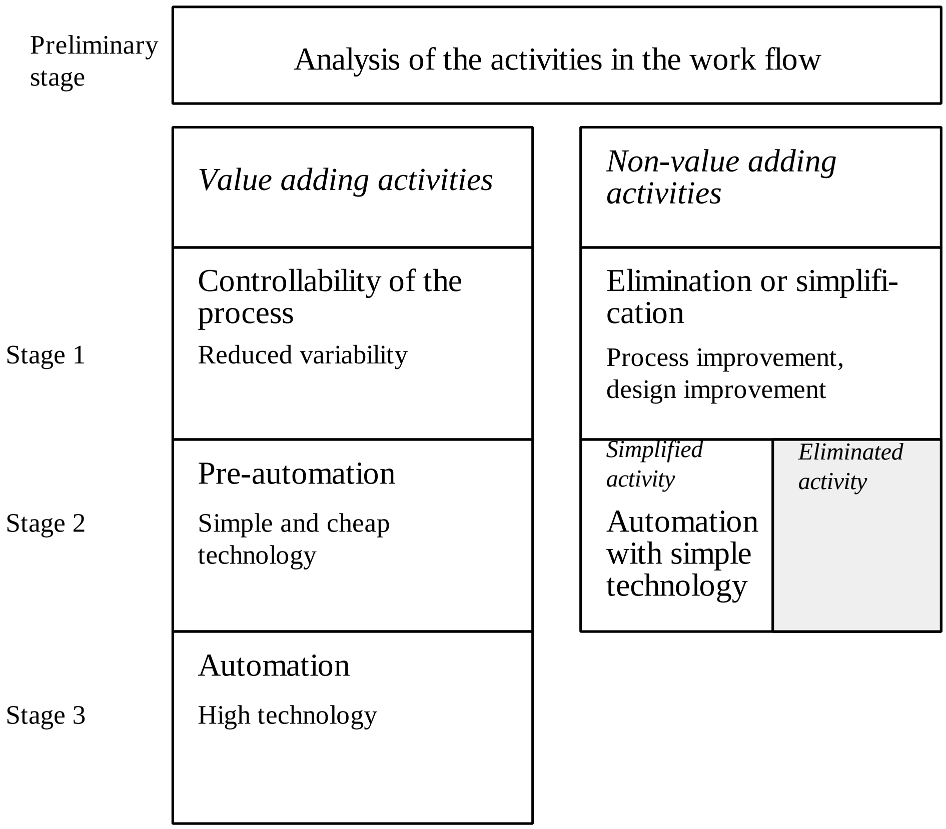

Figure 8. Stagewise development of a production process towards automation (modified from (Béranger 1987)).

Thus, on the way towards automation, the first stage is to enhance the controllability of the process through variability reduction and to suppress non value-adding activities through design and process modifications.

The second stage consists of automating with simple and inexpensive technology. Often the existing machinery is augmented by means of simple mechanical or mechatronic devices, which allow for autonomous operation of the machinery for some period or reduce human activities in the work process.

Only in the third stage, after an accumulation of understanding and process efficiency, will automation with high technology be justified as the next step towards cost reduction.

Continuous improvement should be present in all stages

The role of continuous improvement is significant especially at the stage of enhancement of the controllability of the process and in pre-automation. But also at all stages of automation, the efficiency and yield can be increased by continuous improvement. Thus the overall conclusion is that both the implementation as well as the development of robotics have to be embedded in a process of continuous improvement.

The argumentation presented above, though built upon manufacturing experience, is also generally valid for building construction automation. Due to insufficient attention to process improvement, processes in construction, in general, are not well controlled. As a consequence of this, the share of waste is considerable in construction. In most construction activity flows, it is more profitable to initiate process improvement activities than to automate parts of the present activity flow. On the other hand, a simplification of the respective activity flow, often a result of process improvement, decreases the investment needs for automation and thus increases its profitability. Process improvement is both economically and technologically a precondition for automation in construction.

Of course there are cases, especially in heavy civil engineering, where operations already are highly mechanized or automation is necessary for safety reasons. Automation with high technology may be the right goal in these cases.

In practice, the need for process improvement has not often been clearly recognized, and consequently there is a twofold attitude to construction automation. A somewhat misplaced optimism is shown especially by researchers[8], who do not always see the necessity of getting construction under control as the first step towards automation. On the other side, the construction industry views automation with great doubts, because it is well aware of the out of control situation. However, the industry does not usually perceive any remedy for smoothing the way for automation.

Therefore, construction automation research should also investigate the stages preceding automation (i.e. all items in Figure 8). Rather than solely trying to promote technological solutions, attention should also be directed to the development of design principles of construction tools and machines and related material work flows in general. Another necessary role for R&D is to support practical efforts towards enhanced process controllability, suppression of non value-adding activities, and pre-automation with simple technology. The trend will surely be towards construction automation, but in the form of incremental development, rather than through a long leap.

6.4 Research and education in construction

6.4.1 Obsolete conceptual basis

Current academic research and teaching in construction engineering and management lies on an obsolete conceptual and intellectual basis. This situation is shared by many related fields from which construction management has drawn theories, methods and techniques: industrial engineering, accounting, organization theory, and management strategy theory.

As mentioned earlier, the new production philosophy has evolved as an engineering based methodology, and theory formation has been lagging behind actual practice. The new philosophy's critique of established theories has been implicit and it has come from a surprising direction. Not unexpectedly, the response of academic researchers and educators has been slow and skeptical.

However, in some fields this paradigm shift is already clearly underway. In industrial engineering, tens of books on the new paradigm have already been written, some of them textbooks (Black 1991), and corresponding material is increasingly used in curricula. It is not an exaggeration to say that all books have to written anew, and all old truths have to be reconsidered. Accounting provides another example.

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8 Including the present writer, before his conversion to flow thinking!

As for construction management and engineering, there is yet hardly any sign of a paradigm shift. However, this field can avoid addressing the same fundamental questions with which the neighboring fields are currently struggling.

The lagging response of academic research and teaching seriously hamper the introduction of the new philosophy in construction. In consequence, theoretical understanding of the new approach does not accumulate; however, such understanding is sorely needed for making the new approach teachable and researchable.

Thus, it is urgent that academic research and education address the challenges posed by the new philosophy. Otherwise, a decreased relevance of academic research will be the outcome.

6.4.2 Lacking foundations of construction management

It was argued earlier, in section 4.1, that our empirical knowledge and theoretical understanding of construction is shallow and fragmented. We know little of what is happening in construction projects; only in the last few years has the extent of quality deviations and costs, for example, been subjected to direct analysis. However, quality costs are only the tip of the iceberg of all non value-adding costs. Construction related theories, or sound action principles based on them, are scarce.

It seems that the distribution of the present research efforts in construction is not balanced. The great majority of long term research undertakings aim at applying new tools from other technological fields, like information technology, artificial intelligence and robotics, to construction tasks, whereas the conceptual and theoretical foundations of construction get rather modest attention. However, as argued earlier, major payoffs could be realized through developing these foundations.

It is not an exaggeration to say that the new conceptualization opens a practically new research frontier. As stated earlier, the development of the new production philosophy has been based on individual vision and pragmatic, shop-floor experiments rather than breakthroughs in the theory. The practical validity of the philosophy has been proved in real life implementations. Thus, rigorous validation and explanation of these principles and methods should be included in the research agenda. Examples of new research themes raised by the new conceptualization include the following:

- concepts and taxonomies for defining design and construction processes
- flow oriented site production planning and control tools
- measures for construction processes
- new non-hierarchical organization forms for site work
- procurement methods which advance process improvement.

6.4.3 Formalization of the foundations

However, increased knowledge of foundations is not sufficient; the foundations have to be formalized. In manufacturing science, this has been suggested by several authors. The Committee on Foundations of Manufacturing states that there is a need for an explicit core set of principles, on the basis of which the manufacturing process, as a totality, could be analyzed, designed, managed and improved (Heim & Compton 1992). Burbidge (1990) urges that hypotheses be formulated that could be subjected to rigorous testing, with a view to their acceptance or rejection. The trend towards formalized paradigms is further supported by developments in artificial intelligence. In model based reasoning, a model, heuristics, etc. are formalized for the subject considered.

The endeavor of Plossl (1991) gives a good example of a formalized foundation. He defines a basic law of manufacturing with four clarifying corollaries (section 2.3). He further presents 30 fundamental principles of manufacturing and 10 strategies for applying them. Another interesting approach promoting axiomatic principles for design is presented by Suh (1990).

These arguments in favor of increased formalization are also directly valid for construction engineering and management.

6.5 Conclusions

The attitude to the new production philosophy in construction provides for a paradox: It contains a promise of tremendous possibilities for improvement and of a solution of the chronic problems of construction; however, the interest of both practitioners and academicians has been at best lukewarm.

All in all, the example of manufacturing and pioneering companies in construction show that there is a body of principles, methods and techniques, which are worthwhile to be understand and adopt in construction. They make up a paradigm shift, that will be a long transformation process of both practice and theory of construction engineering and management. The momentum of this paradigm shift has only started to gather. This situation provides opportunities for early adopters to gain competitive benefits.

7 Summary

A new production philosophy has emerged, with origins tracing back to development and experiments of the JIT production system and quality control in Japan in the 1950's. Now the new production philosophy, regardless of what term is used to name it (world class manufacturing, lean production, new production system, JIT/TQC, time based competition), is the emerging mainstream approach practiced, at least partially, by major manufacturing companies in America and Europe. The new philosophy already has had profound impact in such industries as car manufacturing and electronics. The application of the approach has also diffused to fields like customized production, services, administration and product development.

The conception of the new production philosophy evolved through three stages : It has been viewed as a tool (like kanban and quality circles), as a manufacturing method (like JIT) and as a general management philosophy (referred to, for example, as world class manufacturing or lean production). The theoretical and conceptual understanding of the new production philosophy is still incomplete.

The core of the new production philosophy is in the observation that there are two kinds of phenomena in all production systems: conversions and flows. While all activities expend cost and consume time, only conversion activities add value to the material or piece of information being transformed into a product. Thus, the improvement of flow activities should primarily be focused on reducing or eliminating them, whereas conversion activities should be made more efficient. In design, control and improvement of production systems, both aspects have to be considered. Traditional managerial principles have considered only conversions, or all activities have been treated as though they were value-adding conversions.

Due to these traditional managerial principles, flow processes have not been controlled or improved in an orderly fashion. This has led to complex, uncertain and confused flow processes, expansion of non value-adding activities, and reduction of output value.

A number of principles for flow process design and improvement have evolved. There is ample evidence that through these principles, the efficiency of flow processes can be considerably and rapidly improved:

1. Reduce the share of non value-adding activities.
2. Increase output value through systematic consideration of customer requirements.
3. Reduce variability.
4. Reduce cycle times.
5. Simplify by minimizing the number of steps, parts and linkages.
6. Increase output flexibility.
7. Increase process transparency.
8. Focus control on the complete process.
9. Build continuous improvement into the process.
10. Balance flow improvement with conversion improvement.
11. Benchmark.

Analysis shows that, as in manufacturing, the conceptual basis of construction engineering and management is conversion oriented. Conventional managerial methods, like the sequential method of project realization or the CPM network method, deteriorate flows by violating the principles of flow process design and improvement. As a consequence, there is considerable waste in construction. The problems tend to compound and self-perpetuate.

In project control, firefighting current or looming crises consumes management resources and attention so totally that there is little room for planning, let alone improvement activities. However, because conventional measures do not address it, this waste is invisible in total terms, and is considered to be inactionable. Improvement efforts, like industrialization and computer integrated construction, have often been hampered by their neglect of flow aspects.

Following the lead of manufacturing, the next task is to reconceptualize construction as flows. The starting point for improving construction is to change the way of thinking, rather than seeking separate solutions to the various problems at hand.

Thus, it is suggested that the information and material flows as well as work flows of design and construction be identified and measured, first in terms of their internal waste (non value-adding activities) and output value. For improving these flows, it is a prerequisite that new managerial methods, conducive to flow improvement, are introduced. On the other hand, such construction peculiarities as the one-of-a-kind nature of projects, site production and temporary project organizations may prevent the attainment of flows as efficient as those in stationary manufacturing. However, the general principles for flow design and improvement apply for construction flows in spite of these peculiarities: construction flows can be improved. Certainly it is a core issue to understand these peculiarities and to be able to avoid or alleviate their detrimental effects.

In the construction industry, attention to the new production philosophy has grown slowly. Quality assurance and TQC have been adopted by a growing number of organizations in construction, first in construction material and component manufacturing, and later in design and construction. The new approach, in its JIT-oriented form, has been used by component manufacturers, for example in window fabrication and prefabricated housing. All in all, the overall diffusion of the new philosophy in construction seems to be rather limited and its applications incomplete.

Why has the diffusion of the new production philosophy been so slow in construction? The most important barriers to the implementation of these ideas in construction seem to be the following:

- Cases and concepts commonly presented to teach about and diffuse the new approach have often been specific to certain types of manufacturing, and thus not easy to internalize and generalize from the point of view of construction.
- Relative lack of international competition in construction.
- Lagging response by academic institutions.

However, it seems that these barriers are of a temporary nature. In practice, every organization in construction already can initially apply the new production philosophy: defect rates can be reduced, cycle times compressed, and accident rates decreased. Examples of pioneering companies show that substantial, sometimes dramatic improvements are realizable in a few years after the shift to the new philosophy.

The implications of the new production philosophy for construction will be far-reaching and broad, as they are in manufacturing. The renewal of manufacturing has been realized in a feverish burst of conceptual and practical development. This might also happen in construction. A new set of measures will be used to pinpoint improvement potential and to monitor progress in performance. Existing development efforts like industrialized construction, computer integrated construction and construction automation will be redefined in order to acknowledge the needs for flow improvement. New organizational solutions for construction projects will be introduced to facilitate flow improvement as well as innovation.

Current academic research and teaching in construction engineering and management is founded on an obsolete conceptual and intellectual basis. It is urgent that academic research and education address the challenges posed by the new philosophy. The first task is to explain the new philosophy in the context of construction. Formalization of the scientific foundations of construction management and engineering should be a long term goal for research.

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BRIDGING THE GAPS – TOWARDS A COMPREHENSIVE UNDERSTANDING OF LEAN CONSTRUCTION

Sven Bertelsen[1]

ABSTRACT

Since the start of the work on the Lean Construction theory and methods in 1993, two major contributions have governed the process as seen from practice. One is Lauri Koskela's understanding of construction as a production, based on the Transformation-Flow-Value concept (the TFV-concept), the other is Glenn Ballard and Greg Howell's Last Planner method of production control.

These two contributions still stand as two isolated islands even though a number of ideas have been presented in order to bridge the gap between them, concerning for instance the understanding of project management, the value generation process and the cooperation during the project life cycle.

The paper highlights and discusses the primary understanding behind the two main lines of thinking and proposes minor modifications to the two major theories. Three more viewpoints on construction are then proposed as stepping-stones across the gap between the main islands. The use of these principles in project management is briefly touched upon with a reference to recent Danish experiences.

Finally, areas for further research are proposed.

KEY WORDS

Construction, production theory, Last Planner, complexity, project management

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INTRODUCTION

The work on Lean Construction has up till now to a great extent been focussed on two major areas in the understanding of the application and implementation of the new production principles in construction: Understanding construction as a production, and planning and managing the workflow within the construction process. Lauri Koskela has been the outstanding leader in the first area; Glenn Ballard seconded by Gregg Howell and others in the second.

This paper outlines the two major areas and discusses them briefly. In this, minor revisions are suggested. Even though references are made between these two contributions, they also stand as two islands not firmly interrelated. The paper thus proceeds by suggesting three more viewpoints to the construction process, supplementing Koskela's three basic ones and explaining to a greater extent the generality of the Last Planner methods. Based on this thoughts on a new view upon project management is proposed.

The paper is to a great extent based on the author's experiences from the ongoing Danish development of the construction industry in general and its productivity and value generation in particular. (Bertelsen and Nielsen 1999; Bertelsen et al. 2001)

These experiences are now put into a more scientific framework in a very unscientific way by an author that is not himself a scientist. *It is easier to act our way into a new way of thinking, than it is to think our way into a new way of acting.*[2]

LEAN CONSTRUCTION THEORIES

CONSTRUCTION AS A PRODUCTION

Lauri Koskela introduced his understanding of the construction process in the groundbreaking 1992-paper: Application of the New Production Philosophy to Construction (Koskela 1992). It has been elaborated upon in his later works and has for now found its final form in his dissertation: An Exploration Towards a Production Theory and its Application to Construction (Koskela 2000).

In this, Koskela explains that production since the end of the 18'hundreds has been seen from different viewpoints. First as a line of transformations each adding value to the product, since World War II as a flow taking the time aspect into consideration and a little later as a value generating effort.

Production as Transformation

This understanding means that production can be seen as a number of discrete steps, each independently adding to the value of the product. Optimizing each or any of the operations will move the process as a whole towards an optimized condition.

Construction is normally understood in this way even today, and procurements are made accordingly. Lowest price for each operation, order, contract or purchase is expected to lead inevitably to the lowest total cost for the project as a whole.

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[2] Michael R. Lissack (1996): Chaos and Complexity – What does that have to do with management?

Production as Flow

Based on the example provided by Henry Ford, this concept was introduced by the Japanese car manufacturing industry and developed especially by Shigeo Shingo and Taiichi Ohno (Shingo 1988; Ohno 1978). The works of Womack et al (1990, 1996) introduced the concept to the Western industry in a popular form in 1990 by coining the term *Lean Production.*

From this point of view, production is seen as a series of activities, where some are adding value, others are not. The objective in optimizing the process is thus to reduce the non-value adding activities and to optimize the value adding ones.

As it can be found that there are more non-value adding activities than value adding, this moves the focus from the optimization of the value generation to the reduction of waste.

The construction industry has yet to understand this. The perspective of time is still defined as the time used for the transformations only, not as the sum of the time spent on transformation *and* on the non-value generating activities: inspection, transport, and movement.[3] And the construction has indeed quite a lot of such activities. Hammarlund and Rydén (1989) show that two thirds of Swedish plumbers' working time on the construction site is used on such non-value generating activities, a fact which is confirmed by Nielsen and Kristensen's (2001) studies of the erection of prefabricated concrete walls on a Danish construction site.

Experiments using just-in-time logistics in the construction industry have demonstrated substantial benefits, but the methods have been very hard to implement in general. The reason is that an efficient flow of materials to the construction site calls for a more reliable work planning than construction can normally provide. (Bertelsen and Nielsen 1997)

Production as Generation of Value

As production became more lean – and by that also more efficient – the market started calling for more interesting products. The mass produced product went out of fashion, and the individualized product came in. Production became perceived as a value generating activity, and the process had to become agile, if it wanted to survive.

The construction industry is a service provider. Its production is performed by a combination of trades, and it has always been oriented towards generating value. It is the nature of service and it is what the industry believes it provides. But the industry – not having a well-defined product – has no tradition of really looking into what the true value of its output is. The client's value parameters are not stated clearly at the outset of the project and their fulfillment is not monitored systematically through the project life cycle.

Discussion

The TFV-concept opens up a complete new view upon the construction industry, and it gives rise to new approaches to the management of the process, as discussed later.

However, Koskela's perception of the differences between transformation and flow differs somewhat from the Japanese understanding as expressed by Shingo (1988). Koskela understands transformation as discrete events, all adding value to the product (barring defective work). Flow is seen as the chain of transformations inter-linked by

[3] These four classes of activities or process stages were originally introduced by the Gilbreths (1922)

other events such as inspection, transport and waiting, not adding value to the product.

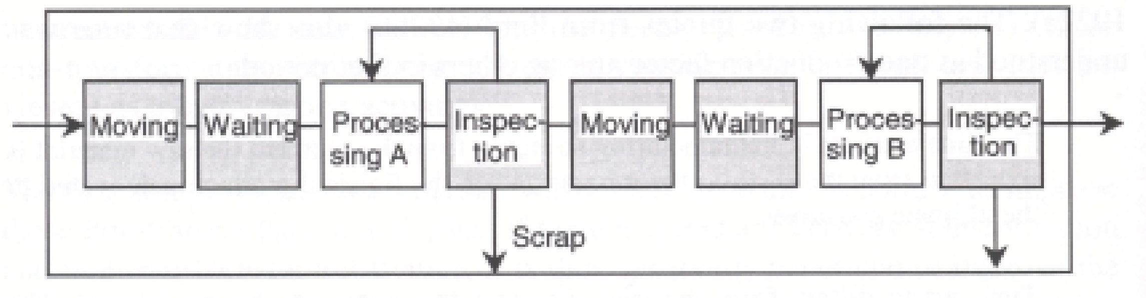

Figure 1: Production as a Flow as understood by Koskela (2000)

Shingo, on the other hand, explains production as a series of processes, each drawing on one or more operations. He claims that operations – the work undertaken by men and machines – and processes – what happens to the product along its travel through the production system, are phenomena lying on two different axes. Even though Shingo does not deal with value as a specific issue it can be said that in his view processes may be value adding or not, whereas operations are always just the carriers of costs. It may also be said that the Japanese understanding of the production as a value generation phenomenon is taken hand of through the design transforming the customers value perception into the product specification.

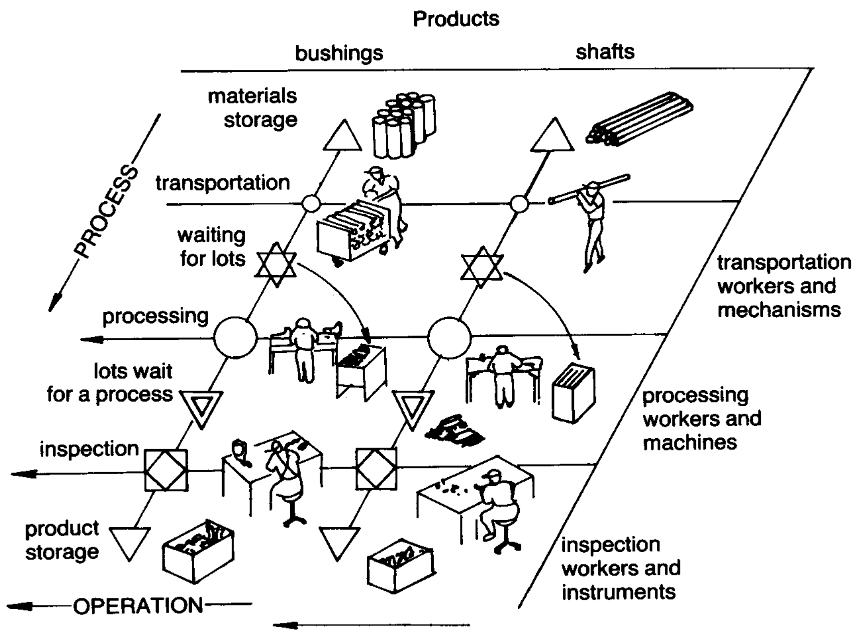

Figure 2: Production as Operations and Processes as understood by Shingo (1988)

Koskela's definitions are indeed the better in explaining the understanding of production from a historical as well as a theoretical and an economic point of view. But Shingo's may be more suited for the understanding of the nature of the construction process from an engineering viewpoint, and thus in understanding the nature of project management.The implications of this will be elaborated upon later.

MANAGING THE CONSTRUCTION PROCESS

Last Planner

The Last Planner approach to the planning and management of the construction process was introduced by Glenn Ballard at the first meeting in the International Group for Lean Construction – IGLC-1 in 1993 (Ballard 1993).

The principles were further elaborated upon at IGLC-2 in 1994 and by the paper: Lookahead Planning: the Missing Link in Production Control, presented at IGLC-5 in 1997 (Ballard 1997) the Last Planner system was complete as a useful tool to be introduced broadly in the construction process. (Bertelsen and Nielsen 1997)

The general idea is that in order to obtain an even workflow, a weekly work planning and a careful monitoring of the plan performance is needed. This takes place through the Last Planner, prepared at the site, as close as possible to the week in question. The Last Planner defines what *will* be done.

An important tool in the Last Planner toolbox is the Percent Planned Completed – PPC. PPC is monitored on a weekly basis and provides a measure of the plan reliability, which is an important prerequisite for the even workflow.

In order to ensure a sufficient workable backlog, the Lookahead Plan supplements the sliding window represented by the Last Planner. The Lookahead Plan is another sliding window looking 5-8 weeks ahead. This plan ensures 'sound' work packages, i.e. work packages for which all constraints are removed. The Lookahead Plan expresses thus what *can* be done.

Above these two plans lies a third – the Master Schedule – identifying all the work packages and their sequence for the job in question. This plan defines what *should* be done. The whole planning system is dealt with in detail in Ballard (2000).

Discussion

The Last Planner method has proven itself a very useful tool for the management of the construction process, and continuos monitoring of the planning efficiency through PPC gives rise to an ongoing improvement, which often ensures a steady stabilizing of the work flow and an improvement in the productivity. (Christoffersen et al. 2001)

The Last Planner thus stands as the landmark for lean projects and PPC as the signboard for posting the success of the implementation of the principles.

The Last Planner is developed as a tool for obtaining even workflow mainly. However, it may be more than that. Several other strategies in making the construction process more smooth and efficient seem to lead to the Last Planner principle as well. One example is the system for materials management developed in Denmark in the early 1990es (Bertelsen and Nielsen 1997), but also managing the flow of information seem to give rise to tools like Last Planner. Both experiences tie Last Planner nicely into Koskela's understanding of construction as a flow. Koskela (2001) looks at Last Planner from the perspective of language/action, small wins and Management-as-organizing and Management-as-learning. And recent Danish experiments (not yet reported) with self managing construction sites using multi-skilled gangs, as well as studies of safety and hazard on lean sites (not yet reported) point at the use of planning principles very similar to the Last Planner.

These observations raise the question whether Last Planner is a tool based on a generic characteristic lying deeper in the construction process. This characteristic may be the complex nature of the project and of the system undertaking the process; a hypothesis dealt with in further detail in a later section.

LEAN CONSTRUCTION PRINCIPLES

Womack and Jones

The lean thinking was originally outlined by Womack, Jonés and Roos in their 1990 work and was further elaborated upon in the book *Lean Thinking* by Womack and Jonés (1996). The guiding principles were now coined:

- Identify the value stream
- Optimize the operations that generate the value
- Make the product flow, waiting is waste
- Use a pull logistic
- Seek perfection in all operations

Even though these principles have been very useful in the implementation of lean thinking in production as well as in construction, their validity can be discussed. For one thing, the principles do not focus on minimizing waste in all its forms, only on waste in the form of waiting. Also, waiting is not always bad. Certain buffers may be needed in order to optimize the throughput, as Goldratt has shown by his Drum-Buffer-Rope principle (Goldratt 1984, 1985). Also the workable backlog in the Last Planner system represents waiting.

But more important, neither Womack and Jones nor Goldratt focus really on the concept of generating value Their primary goal is reducing costs. This may be a valid strategy when looking upon the mass producing industry, but looking at project based one-of-a-kind productions such as construction, this is indeed a serious mistake.

Glenn Ballard

The validity of Womack and Jonés' formulation of the lean principles was challenged by Koskela (2000) who – inspired by the accepted doctrine of operations management – stated the objectives as: While getting the project done, maximize the value and minimize the waste. These objectives were further elaborated upon by Ballard et al. (2001) who divided the principles in a number of strategies and methods which can be used in the implementation of the lean principles not only in construction, but in any project delivery process

It is obvious that Koskela's formulation of the objectives is more precise and is covering more aspects as well. However, it omits a very important point in the Japanese thinking: the ongoing improvement, as expressed in the last of Womack et al's principles and also included in a number of Japanese inspired management theories such as Total Quality Management. As dealt with later: living in a world that is not perfect, one must always seek towards perfection without ever getting there. Thus it is here proposed that the lean principles should be:

While delivering the project, an ongoing effort should be made to maximize the value and minimize the waste.

This formulation of the objectives will be used as the guiding principles to bridge the gap between Koskela and Ballard.

Discussion

Even though the Last Planner can be linked to the theory of construction as a flow, which Koskela (1992) tries explicitly, some more views on construction may be useful in firmly bridging the gap between these two main contributions and in understanding the construction process' peculiarities. One reason for looking for such a deeper understanding is that the flow concept can not in itself explain the demonstrated success of planning with a short time horizon, as used in the Last Planner. Why not just plan in detail through the master plan and use that for the process control? Some deeper understanding of the construction process is needed in giving the reason for the fact that this system approach is not working.

Three such steppingstones between Koskela's TFV concept and the Last Planner are proposed in the following section in the format of construction as a one-of-a-kind-production; construction as a complex system; and construction as cooperation. Together with Koskela's three fundamental principles – TFV – these three new perspectives can be used to establish a new view on the construction process in general and its management in particular, as outlined in the last part of this paper.

THREE STEPPING STONES

CONSTRUCTION AS A ONE-OF-A-KIND PRODUCTION

Construction is a production of unique products. No two projects are alike. Not only are the projects different in their look and feeling, they are different in their details as well. Construction projects are not combinations of otherwise standardized details as found in the modern car production. They are products, which are different in any scale.

Construction is not the only industry that manufacturers a unique product. Movies and IT-systems both have much of the same uniqueness. But movies as well as IT-systems can be produced without the rigid assembly sequence that is another characteristic of construction. The development of IT-systems takes place as modules, which can be developed and tested as individual products before the final assembly. And any defect module can be replaced after the final system test.

Moviemaking has many of the same characteristics. A great part of the production can be made as a top down process, where the shooting takes place in a sequence best suited the production efficiency and the final assembly at the cutting table is carried out as a successive approximation to the final result. Even rework in the form of re-shooting a scene or two is possible within reasonable cost.

And both productions to a great extent take place in controlled environments such as studios or offices.

Construction on the other hand executes a production, which to a great extent is locked to a rigid assembly sequence, where the operations can not be interchanged. Furthermore, most of the production takes place in the haphazard and temporary environment of the construction site.

Only in the early design phases can construction make use of the top-down process best supporting creative work. While moviemaking and IT systems keep the top down process in operation almost until the final production stages, construction is forced to abandon this approach before 10 percent of the process is completed. This means that the cooperation between the customer and the production team should be very close and well structured in the early phases. But unfortunately, such a close cooperation is the exception rather than the rule. Far too often is the drafting started without a detailed analysis of the client's needs and requirement for the work in question, and a diligent preparation of the design brief.

After the completion of the first design phases changes and rework are so expensive that they are commissioned only when really necessary – which they often are – and then with the associated high costs and delays as consequences. And even worse: changes and rework add substantially to the already great dynamic in the complex system which construction is.

CONSTRUCTION AS A COMPLEX SYSTEM

The understanding of complex systems is a science coming more and more into focus by the development of computer systems capable of simulating their behavior. More and more is it recognized that almost all living systems and most of the systems in society are complex and at the same time highly dynamic (Waldrop 1992).

The study of complex systems moves the focus from studying the elements in the system – the agents – to studying their connections and thus the network they form. By doing so, a great similarity between otherwise different systems can be found, from the system of cells in living organisms, to the anthill and the freeway traffic, and to the construction production system as well. By simulating such systems in computers their characteristics can be isolated and studied in detail, including how the strength of the interconnections influence the network behavior (Kauffman 1995).

It can be shown that such systems often exist on the edge of chaos, meaning their behavior is predictable in any detail only a few time-steps into the future. Whether the system shows this chaotic behavior depends on the situation, particularly how close the elements of the system are coupled. A well-known example of such systems is the weather being close to the edge of chaos.

The flow of traffic on a freeway system is another example. If the traffic becomes too dense, small disturbances in the traffic flow can release waves of traffic jam flowing backwards through the system and staying there a long time after their cause has disappeared.

Construction has many of these features as dealt with in more detail in Bertelsen (2002). The construction project is a sequence of coupled processes leading to the constructed artifact. The processes are all undertaken in the form of operations executed by men and machines provided by the trade contractors participating in the project. But these contractors all work on other construction projects at the same time as well, utilizing the same resources in all their contracts and thereby forming another closely coupled network across the project borderlines, and virtually to the whole construction sector in the district or even the country. Kauffman (1993, 1995) studies the nature of such networks in great detail and demonstrates that there need only be a few couplings from each node to randomly chosen other nodes before the whole network acts as one. The transition from individual nodes or small clusters to a whole takes place almost suddenly, when the number of couplings is increased, just like a phase transition.

Not only is the workflow through the network of activities for the project in question uncertain, because only the value generating processes are mapped, omitting the inspection, transport and waiting processes in between. But also the couplings to the resource networks are totally unknown and ever changing. These couplings are certain to be tight because of the agents' efforts to maximize their resource utilization and the dynamic in the whole network is great as well, because of the fluctuations in workflow.

The construction activities within an economic system are not independent processes, but form one big system operating on its own without any over all management. Any attempt to establish such management is deemed a fiasco – the system will freeze and all processes almost certainly stop.

Brousseau and Rallet (1995) point at the construction industry's peculiarities, lack of a formal management being one of them. Also Tavistock (1966) puts focus on the unusual form of management found in construction compared to manufacturing practice. Looking at construction from a complexity point of view makes this peculiarity quite natural. Highly complex system can not be managed by a formal management approach, but must be given a high degree of freedom to organize and manage themselves – order for free, as Stuart Kauffman (1993) coins the phenomenon.

Goldratt (1984, 1985) presents a method for the management of a production system consisting of shared resources for several products called the drum-buffer-rope principle. Goldratt looks at a closed system within one economy only though, whereas construction forms an open system guided by a multitude of economies. It seems that construction must learn how to live with this chaotic situation.

As in many complex systems of this kind, the same patterns can be found in the details as in the whole. The complexity of the whole construction sector can – on a smaller scale – also be found within the project and even down in the individual task. This makes any long-term predictions about the execution of the work next to impossible, no matter how advanced tools are brought into operation.

However, this phenomenon is not understood by the industry. Project management is based on the assumption that construction is an ordered system, which can be planned in great detail and executed in all details according to the plans. The result is well known: the plans are not followed, and closer investigation reveals that there exist a number of unofficial and unauthorized management systems to ensure that the work gets done (Tavistock 1966).

CONSTRUCTION AS COOPERATION

Looking at the construction process as the phenomenon it really is: a complex production of a one-of-a-kind product involving big capital investments, the organization and management comes into focus. What happens at the construction site can be seen as a production in a virtual company.

A production takes place and people meet to undertake it. *But they do not do so as a production company!*

The construction process has none of the characteristics of the modern manufacturing company. Sub-optimization is found everywhere and nobody has the over all success of the production as their personal success criteria.

The form of cooperation found in construction has long since been given up by other industries, even the army. Orders and dress downs and only limited respect for the professionalism and the work of others are the rules in construction. The result is everybody’s fight against everybody, where the project management is forced to take the role as the umpire, adhering to the formal rules instead of establishing an efficient, common company culture.

The temporary nature of the project makes it further difficult to establish a positive cooperation. In systems where cooperating as a whole is to the benefit of all, but where bigger benefits can be gained for the individual by cheating, the temptation to cheat becomes great, when the participants know that the cooperation has a limited duration. Particularly so towards the end of the cooperation (Thomassen 1999).

And the construction process is just such a situation. Everybody is here for a short duration and each has his own business to attend to. As an individual or as a trade contractor. And nobody tries to generate team building and cooperation. Just the opposite. Even the management stands on their rights and on the contractual details without any concern for the real benefit for the project. No wonder things are as they are!

That things are bad may be hard to prove. But experiments with new forms of cooperation and a new management style almost immediately show a better performance through a more efficient process (Christoffersen et al. 2001).

DISCUSSION

Looking at the Last Planner system in the light of these three new views may lead to a deeper understanding of why the system is so useful in practice. The one-of-a-kind nature of the project makes it very hard to establish a reliable production schedule. Too many things are uncertain and these uncertainties add up along the chain of activities as shown by Koskela (1999, 2000). The short horizon for the planning of 'will do' is thus an elegant way of overcoming this uncertainty aspect.

The same goes for the complex nature of the construction process and industry. Complex systems often show a high sensitivity to initial conditions making them in practice unpredictable for more than a few steps into the future. The feature is often referred to as *chaos*. From this aspect Last Planner can be seen as the establishment of a local window of order in an otherwise chaotic situation.

Finally, Last Planner can be seen as a means for establishing a co-operation between equal parties at the construction site. The planning process executed as action learning supports the cross trade cooperation and brings a mutual understanding of the importance of an even work flow to 'the men on the scaffolding.'

These interpretations of Last Planner seem to support the hypothesis that Last Planner is a tool reflecting the generic nature of the construction process.

THOUGHTS ON PROJECT MANAGEMENT

Having established a theoretical understanding of the process and its nature, an operative wording of its objectives and a value oriented process model, it seems natural start looking at the management of this system.

Several authors have shown that the traditional management of the construction process is very poor. Indeed, it has been said that the construction management is the management of contracts only (Koskela and Howell 2002).

Recent experiments with a divided project management, where the management of contracts (or operations) are separated from the management of the process, and where a separate management of the value generation have shown remarkable results in the form of improved production, shorter production time, lower costs, increased workers' safety and a higher client's satisfaction (Christoffersen et al. 2001). It is the author's feeling that many of the characteristics of this new kind of project management can also be found in most of the successful implementations of the lean principles in other countries, even if they are not recognized and formalized as in the Danish implementations. Bertelsen and Koskela (2002) looks deeper into project management along these lines.

FUTURE RESEARCH

The above outlining of the lean landscape as shown from a Danish viewpoint calls for a future research besides the mainstream IGLC work.

One important issue is the understanding of construction from a complexity point of view – a completely new and very challenging approach. This will inevitably bring the co-operation between the participants in the form of an integrated but temporary human system – not least the cooperation on the workers' level on the construction site – into focus as well. Modern management theories such as management as learning and management by walking around should be considered in the context of managing the construction process.

Project management should be studied in a broader context as well, not least value management. Value is a personal and situational parameter. The understanding of its meaning in the light of the construction project as a complex system generating artifacts with an expected long lifetime, several users and huge impact on our build environment, is of paramount importance for the proper implementation of value management. At the same time, experiences for the ongoing Danish experiments with the form of project management should be reported and analyzed from a theoretical point of view.

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Estudio sectorial: productividad en la construcción

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Resumen

El año 2004 encuentra a la industria de la construcción en un estado de incertidumbre, viviendo el inicio de un proceso de reactivación, luego de haber atravesado su peor crisis de los últimos 30 años. Esta crisis se llevó consigo a los talleres metalúrgicos y a los operarios calificados en distintos oficios, desarmó a los más importantes estudios de arquitectura e ingeniería y terminó con la mayoría de las empresas constructoras pequeñas y medianas. Este artículo, escrito desde la óptica de un *practicioner* de la industria, está organizado del siguiente modo: En la sección 1, se describen las dificultades del sector, desde distintos puntos de vista. A pesar de las dificultades, la sección 2 es una invitación a trabajar por la productividad, seguridad y calidad en la industria. La sección 3 describe algunas limitaciones de los profesionales que trabajan en la industria que contribuyen al origen de los problemas analizados. La sección 4, la más larga del trabajo, es una propuesta integral para mejorar la calidad y productividad en la industria de la construcción. La sección 5, finalmente, presenta algunas conclusiones del trabajo y da recomendaciones basadas en él.

1. Dificultades que atraviesa el sector

Comenzamos describiendo en esta sección los principales factores que afectan hoy a la actividad. Ellos están vinculados con el mercado, los recursos humanos, la productividad, la seguridad, la calidad y sus normas, el cumplimento de plazos y los productos de la industria. Examinemos estos factores.

Mercado: El sector privado se está lanzando a invertir en pequeños desarrollos, pero sin crédito para constructores ni para compradores, este segmento no logra despegar con volumen para mover la economía. El sector público es una gran promesa, tal vez se cumpla y cambie el panorama en 2004. Las pocas empresas constructoras que quedaron en pie se debaten internamente sobre la posibilidad de invertir y crecer o quedarse quietos esperando que el incipiente efecto reactivador se instale para quedarse.

Recursos humanos: La construcción siempre tuvo operarios y supervisores poco calificados, pero conocedores de su oficio. En los últimos años esto ha empeorado pues, ante la caída de la construcción, los trabajadores más capacitados se han dedicado a otra actividad, por lo que cuesta muchísimo encontrar hoy, a pesar del alto desempleo, trabajadores con un nivel propio de productividad razonable.

Productividad: Si a la falta de capacidad de los trabajadores se le suma la desinversión en equipamiento (con precios a "valor dolarizado") se llega a valores de productividad muy bajos, mucho más bajos que en los países desarrollados.

Seguridad: Existe un alto nivel de inseguridad. Las empresas pequeñas y medianas desconocen la necesidad de aplicar normas de seguridad y no hay controles suficientes del estado.

Cumplimiento de plazos: Como una constante propia de nuestra sociedad, ni los estudios de arquitectura, ni los asesores, ni los proveedores de insumos, ni los subcontratistas de mano de obra, ni los talleres que producen bienes semi-elaborados cumplen con los plazos pactados. Esto obliga a permanentes reprogramaciones, negociaciones, mayores gastos y caída de la productividad.

Normas de calidad: No están calificados ni cumplen normas de calidad el 90% de los proveedores de insumos, el 100% de los subcontratistas, el 95% de los estudios de arquitectura e ingeniería. Tampoco cumplen normas de calidad el 100% de las constructoras pequeñas y medianas.

Productos: Los productos son los nuevos proyectos. Casi todo es nuevo, de una obra a otra. Los productos terminan siendo trajes a medida, únicos, irrepetibles, caros, a gusto del cliente. De una obra a otra las empresas constructoras van cambiando de subcontratistas, buscando alguno que cumpla. Así, no se produce el desarrollo de los proveedores y subcontratistas y no hay curva de aprendizaje posible, como se da en otras industrias. No hay repetición que permita medir estándares, controlar la eficacia (cumplimiento de objetivos de cantidad y plazo) y la eficiencia de uso de los recursos (standard real / standard teórico). A su vez, las variables macro de la economía, (devaluación, inflación, pesificación, dolarización, aumentos salariales por decreto) impiden un claro análisis de efectividad (rentabilidad del proyecto).

2. Pensando en crecer

Luego de este panorama que parece sombrío, no debemos quedarnos congelados aceptando nuestra improductividad como un paradigma inmodificable, sino que debemos aprovechar el momento de incipiente reactivación de la economía para encontrar en nuestros errores del pasado un conjunto de oportunidades donde poder focalizar nuestros esfuerzos y dar, verdaderamente, un paso hacia adelante en la calidad y la productividad de nuestras compañías.

Es este el momento en que estamos relanzando proyectos dormidos. Es este el momento en que nos vuelven a contactar viejos clientes para saber "en qué andamos". Es el momento en que nos llaman nuevos clientes que fueron defraudados por empresas ya desaparecidas. ¿Qué les diremos? ¿Que no aprendimos nada de la crisis pasada? ¿Que haremos todo igual ? ¿Por qué confiarían en nosotros?

Las empresas que no encuentren las oportunidades de mejora en sus errores del pasado y que no entiendan que deben subirse al tren de la productividad caerán, como cayeron en el pasado.

La construcción se debate en el camino de la calidad y la productividad, sin rumbo cierto y las empresas constructoras no desarrollan a proveedores o subcontratistas bajo conceptos de aseguramiento de la calidad y mejora de productividad. Los plazos, las especificaciones, la seguridad y la satisfacción de los clientes se despedazan en medio de procesos constructivos torpes y artesanales. ¿Qué es lo que nos pasa en la construcción?

3. Diagnóstico

Los constructores, arquitectos o ingenieros, creemos que la capacitación técnica adquirida en la universidad es suficiente para administrar empresas y recursos humanos, proveedores y subcontratistas, clientes y normas. Sin embargo no nos han enseñado a trabajar con gente. Somos ciegos al contexto social. No hemos desarrollado habilidades o competencias genéricas que nos asistan a crecer como empresarios autosuficientes.

En general, luego de incorporar en nuestra cabeza competencias específicas de la propia carrera, no seguimos incorporando técnicas que nos ayuden al desarrollo de una visión, de una misión ni de una estrategia competitiva. No sabemos cómo armar planes de negocios, que satisfagan a las necesidades de nuestras compañías y de nuestros circunstanciales o potenciales clientes.

Los constructores trabajamos con la palabra, todo el día, todos los días. Sin embargo, no hemos recibido ninguna capacitación para hablar. No conocemos el poder del lenguaje. No sabemos manejar el texto y el contexto de nuestras presentaciones y solicitudes, por lo que terminamos dando órdenes que queremos hacer cumplir sin lograr el convencimiento de los demás.

Por supuesto, somos testigos de que todo esto se traduce en (magros) resultados.

Es entonces que partiendo de nosotros nacen los problemas. Y es en nosotros donde debemos encontrar la solución. Debemos olvidar la miserable explicación de que el mundo está contra nosotros. Debemos ser responsables. Debemos ser capaces de dar respuestas. Debemos tratar de trascender en el alcance de nuestro propio desarrollo para que el entusiasmo por el hacer bien las cosas nos rodee.

4. Propuesta de trabajo

El camino para subir en la escalera de la calidad y la productividad en la construcción sólo se podrá lograr a través de una gestión profesional de máxima calidad, que sea el motor que trabaja en la modificación de los problemas diagnosticados. Por lo tanto, consideramos que se debe capacitar, desarrollar, medir y analizar, la *calidad de la gestión* de los profesionales de la construcción. Esta debe ser la base de trabajo en la agenda de los máximos directivos de los estudios de arquitectura e ingeniería, de los desarrolladores inmobiliarios y de las empresas constructoras pequeñas, medianas y grandes.

El proceso de cambio debe estar en la agenda de cada profesional, que debe autoevaluar sus falencias y trabajar en sus organizaciones sobre algunos de los siguientes tópicos:

4.1 El constructor debe ser el líder del cambio

Se debe iniciar un proceso de cambio que afecte todos los pasos que integran el proceso de construcción, desde el nacimiento del proyecto hasta el momento de la entrega y puesta en marcha. El cambio debe ser liderado por los constructores, quienes deben encontrar los caminos para eliminar, una a una, las deficiencias que hacen que la construcción sea la mas "imperfecta" de las industrias. El proyecto debe estar incorporado a su mente. Debe estar "in corpore". Lo debe sentir dentro suyo, para poder iniciar el proceso de cambio.

" El cambio es hacer lo que otros creen que no podemos hacer. Hacer el cambio ya, para evitar dudas y desconfianza."

Para cambiar, el constructor:

Debe estar convencido

Debe reconocer falencias

Debe escuchar al cliente

Debe analizar contradicciones

Debe predicar con el ejemplo

Debe entender que el cambio "duele".

El constructor debe ser un líder promotor del proyecto:

Para persuadir y direccionar la reingeniería del proyecto del cliente

Para promover el interés y respaldo de su propia empresa

Debe formar un equipo de cambio

El constructor debe ser líder de los procesos constructivos:

Para aplicar principios de constructibilidad al proyecto.

Para formar un equipo ejecutor del proceso constructivo

Para liderar el equipo de asesores externos que mejores los procesos

El profesional no puede caer en la trampa clásica de explicar los malos resultados. No puede funcionar la construcción a través de "profesionales explicadores" sino a través de *líderes*. Deben eliminarse del lenguaje operativo los términos: *le dije, me dijo, le avisé, lo llamé, me preguntó, parece que, ...* y el resto de muletillas conocidas.

4.2 El constructor debe romper paradigmas

Estamos rodeados de paradigmas: un conjunto de verdades asumidas por el conjunto de los actores que impiden ver la realidad y nos arrastran en la práctica de la construcción con modelos de organización de proyectos perimidos, caros y de baja *perfomance*.

4.2.1 El paradigma de la obra

Siempre se escucha, como una verdad inexorable, que se puede convivir en nuestro ámbito de trabajo con la suciedad, con la inseguridad, con la falta de calidad y con la insatisfacción del cliente **"... porque esto es una obra ...".** Por alguna razón, la estructura mental de nuestra gente impide pensar en la construcción como una industria, adoptando las técnicas de dirección válidas para cualquier tipo de compañía, válidas para fabricar, por ejemplo, autos o medicamentos.

4.2.2 El paradigma del sistema parental

El director de obra da órdenes al jefe de obra. El jefe de obra da órdenes a los subcontratistas. Los subcontratistas dan órdenes a sus capataces. Y así sigue la obra, con órdenes y más órdenes para tratar de hacer cumplir órdenes incumplidas. Perseguimos el control y la obediencia como bienes únicos e irrepetibles. Incluso creo que nos confundimos tanto que no pensamos en cómo hacer la obra sino en cómo hacer obedecer órdenes.

4.2.3 El paradigma de hacer perder al otro

El mercado está revuelto. Hay poco trabajo y una lucha descarnada de precios. Rara vez en la construcción se repiten los lazos cliente - empresa – subcontratistas – proveedores. No se producen alianzas estratégicas, capacitación de proveedores y subcontratistas, capacitación del personal de supervisión ni estandarización de procesos constructivos. Como resultado, los proveedores no se equipan ni adoptan nuestros estándares como propios. La pérdida del ejercicio *win-win* nos significa aumentar nuestras estructuras de seguimiento y control, tratando de evitar que la otra parte nos haga perder.

4.2.4 El paradigma del costo de la calidad

Los constructores ven la calidad como el agregado de costos en sus procesos constructivos. Sin embargo, la calidad está dada por un conjunto de actividades que permiten producir a un menor costo por su diseño, la simpleza de producción, la facilidad de entrega y el cumplimento total de las especificaciones del cliente. Permanentemente, ejecutamos tareas que no agregan valor al producto que recibe el cliente. El cliente sólo paga por el instante en que un material está colocado en su obra, por el instante en que el operario coloca el ladrillo. No paga las horas de transporte, las horas de almacenamiento, los días de espera, el chequeo de los remitos, la emisión de órdenes de pago, el retrabajo una y otra vez...

Si estudiamos nuestros procesos, veremos que por cada operación que agrega valor (el cliente paga por el instante de producción) desarrollamos cientos de actividades que no agregan valor (el cliente no paga por nuestros procesos de compra, transporte, recepción, reejecución, almacenamiento, pagos y cobros, etc.). En general, cuando hablamos de trabajar con calidad, solo nos concentramos en la producción bruta o en la elección del insumo, sin trabajar sobre el conjunto de actividades que no generan valor para el cliente.

Trabajar con calidad consiste, en parte, en reducir al mínimo la ejecución de tareas por las cuales el cliente no paga. Reducir los desperdicios, retrabajos, controles y administración de materiales. Reducir los costos de dirección y supervisión. Trabajar con calidad en hacer las cosas más fáciles, seguras y rápidas.

4. 3 El constructor debe aplicar procesos de mejora continua

Para romper los paradigmas, el constructor debe trabajar en la implementación de procesos de mejora continua. Estudiando el ciclo de vida de distintas empresas, se puede observar que mientras que las empresas desesperadas encuentran el callejón sin salida de la reestructuración o reducción de gastos, las compañías inteligentes han preferido hacer reingeniería de sus procesos e implementar técnicas de mejora continua, arrancando de raíz con los trabajos innecesarios y alineando cada proceso de la compañía en la dirección de la satisfacción del cliente, con claros procedimientos de operación y llegando a la reducción de los tiempos de proceso y la calidad total.

La mejora continua está íntimamente vinculada con la estandarización, como se esquematiza en la Figura 1. La mejora continua (M.C.) nos permite subir, simbólicamente, por un plano inclinado a medida que progresamos. Por otra parte, la estandarización (Std.) impide que nuestra forma de trabajo vuelva hacia atrás (empeore) por efecto de un sinnúmero de factores que, si no se controlan continuamente mediante estándares, llevan a un deterioro de la *performance.*

La pregunta diaria debe ser: ¿Cómo hacemos las cosas más rápido y con menos desperdicio? Hoy las empresas exitosas piden a sus empleados, antes que a los expertos, que rediseñen los procesos y los flujos de trabajo. Las empresas exitosas trabajan en mejora continua sobre el *empowerment* de sus empleados, buscando en la satisfacción de sus clientes la creación de mercados para el futuro. Las empresas desesperadas, aplican la receta del *downsizing*, ajustando e incumpliendo.

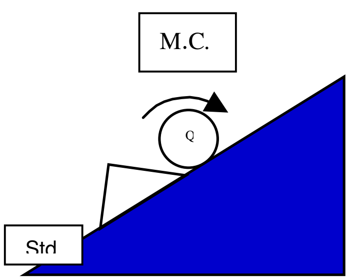


Figura 1. Interacción mejora continua- estandarización

Para implementar un proceso de mejora continua, debemos empezar cambiando nuestras conciencias antes de ponernos a tocar los procesos. Es así, que es aconsejable seguir las siguientes etapas.

La revolución de la conciencia

- Suponer en todas las actividades que el sistema actual de producción es malo.

- Cambiar los sistemas de comunicación entre las personas, encontrando los mecanismos de transmisión de una visión compartida entre los miembros del equipo de trabajo
- El trabajador pasa de controlado a capacitado
- Los supervisores pasan de supervisores a formadores
- Las estructuras, de jerárquicas a planas.

El cambio en los procesos

Es importante diseñar un sistema global de calidad y productividad, incorporando los conceptos y herramientas utilizados por las empresas más exitosas. Entre estos conceptos y herramientas tenemos los siguientes.

- **Mejora continua**
  - Ciclos de resolución de problemas
  - Círculos de calidad
  - Eliminación de desperdicios ("no valores")
  - Nuevos sistemas de información
  - Nuevas tecnologías
  - Sistemas de sugerencias
  - Mantenimiento productivo total
  - Calidad total
  - Producción según programa
  - Organización y disciplina en el ámbito de trabajo
- **Normas de calidad ISO**
  - Revisión de contrato
  - Organización de la obra
  - Programa de calidad del proyecto
  - Control de documentación
  - Identificación y trazabilidad del proyecto
  - Control de procesos
  - Inspecciones y ensayos
  - Control de no conformidades
  - Acciones correctivas y acciones preventivas
- **Capacitación**
- **Trabajo en equipo**

- **Comunicación, comunicación, comunicación**

4.4 Trabajar en procesos de ingeniería de valor

Los constructores debemos examinar de qué manera podemos mejorar nuestros propios proyectos desarrollando procesos de Ingeniería de Valor (**VE**, por sus siglas inglesas). Muchas veces nos preguntamos qué es la ingeniería de valor:

- La Ingeniería de valor no es el arte de minimizar todas las oportunidades de ser creativo en un proyecto.
- La Ingeniería de valor no es la ciencia de minimizar los costos bajando la calidad.
- La Ingeniería de valor es el trabajo aplicado a aumentar al máximo el valor del producto mientras se minimizan los costos

Probablemente, dependiendo de las propias experiencias en las que trabajamos en el pasado, podamos decir que son válidas alguna de las dos primeras definiciones. Pero no debemos equivocarnos. Las dos primeras definiciones corresponden a simples procesos de reducción de costos. El verdadero proceso de Ingeniería de Valor es aquel que agrega valor al proyecto, mejorando plazo, costo y calidad.

En todo proceso de construcción, el 80% del éxito se juega en el primer 20% del plazo, momento en que se toman las decisiones mas importantes de como será el producto. De ahí, que es clave iniciar en forma temprana el proceso de VE, para que sea verdaderamente efectivo. Generalmente, en un proyecto de obra concebido por un dueño, se contrata primero a un arquitecto que desarrolla el proyecto con planos y especificaciones. Luego de una licitación se contrata a un constructor que desarrolla su propia ingeniería, e intenta agregar algo de valor para su propio provecho, porque recibió un proyecto cerrado y definido, en el cual quedaron oportunidades de mejora no aprovechadas. Para nosotros, es mucho mejor para el comitente contratar a un arquitecto y, con el desarrollo parcial del proyecto, seleccionar un constructor que integre el equipo de desarrollo, incorporando al proyecto definitivo valor ganado para el comitente.

¿Usted ve la diferencia? Es clave entender la importancia de encontrar en momento donde debe entrar el constructor dentro de un proceso constructivo. Nuestra idea es que debe entrar lo antes posible, desde el mismo momento del diseño. La VE debe evaluar la filosofía del proyecto, el cumplimiento de las necesidades del comitente y la constructibilidad global de la obra. No debe estar intentando rediseñar el proyecto entero, sino que debe integrarse al equipo de proyecto para sumar valor.

La VE es una práctica cuya meta es, siempre, lograr el valor por el dinero. VE es el conjunto de técnicas que mejora las prácticas que la dirección puede emplear. Su aplicación es exitosa para mejorar la planificación estratégica, la calidad y la durabilidad. Se diferencia de otras herramientas de dirección fundamentalmente en que es multidisciplinaria. Los resultados más importantes son:

- Reducción del plazo total del proyecto: las obras se inician antes (*fast track*) y se hacen mas rápido.
- Reducción del costo directo del proyecto: menores costos de materiales y menor cantidad de horas hombre. Uso más racional de los recursos. Aumento sustancial de la productividad de la mano de obra.
- Reducción de costos indirectos: a mejor constructibilidad, menor plazo, menor supervisión, menor cantidad de retrabajos.
- Mayor confianza de los clientes, mejorando la relación entre las partes por lo que se logra un mejor posicionamiento de cara al futuro.

Para cumplir con los objetivos definidos, el responsable del proceso de VE debe ser cuidadoso en la planificación y en la medición de resultados.

Debe planificar:

- plan de entrega de ingeniería
- diseñar procesos y secuencias
- plan de trabajos, plan de compras y subcontratos

Debe ser preciso:

- control de costos
- control de plazos
- control de calidad
- control de ingreso de suministros
- control de procesos y secuencias
- control de efectividad (rentabilidad del proyecto)
- control de eficacia (cumplimiento de objetivos de cantidad y plazo)
- control de eficiencia de uso de los recursos (stdandard real / standard teórico)
- continua coordinación y actualización de planes y compromisos
- control de servicios generales (ingreso de insumos, administración y mantenimiento de equipos)

4.5 Trabajar en un proceso de *partnering*

Si usted ha trabajado en la industria de la construcción durante algún tiempo, entiende la necesidad del trabajo en equipo. Al contrario de algunas otras actividades, es casi imposible no asociarse con otros y no discrepar en muchísimos puntos. Es clave entonces desarrollar la idea del *partnering*.

En una primera mirada, la idea del partnering parece algo teórica o liviana. En particular, porque siempre se encuentra en los proyectos un importante nivel de hostilidad entre dos o más partes intervinientes. La idea del partnering es reunir a los individuos para encontrar el nivel de acuerdo mínimo necesario para que el proyecto exitoso sea la meta común. Para crear entonces un estado de partnering, se debe empezar a trabajar en conjunto desde el nacimiento del proyecto, para que diseñadores, contratistas y dueños no nos "matemos" luego a lo largo de la construcción del proyecto.

No es cuestión de decir en forma liviana que "somos todos partners", sino que la idea es poner reglas claras de trabajo para poder convivir durante la duración del proyecto. Desde el momento de la redacción de un contrato, se debe pensar de qué forma se pueden alinear los objetivos de las partes. Cómo hacer para reemplazar el concepto multa por el concepto "*success fee*" o premio por resultado. Cómo formalizar la alineación de objetivos del proyecto, donde el arquitecto y el constructor ganen más cuanto menos cueste la obra, cuando se reduzca el plazo y se mejore la calidad.

Las regulaciones de los contratos deben fomentar el juego en que todas las partes ganan. Donde se elija al constructor de la misma forma en que se elige al arquitecto: por sus antecedentes, por su capacidad y porque pretende una ganancia razonable. Debe desaparecer el paradigma de que lo que uno gana es pérdida para el otro.

En el marco de partnering, se puede crear el equipo de base de VE, que debe estar formado por los proyectistas, los dueños, el contratista principal (el gerente de construcciones) y algunos subcontratistas importantes.

El arquitecto es el jugador más importante del equipo de partnering. Es el primer contrato del dueño, quien interpretó su idea primitiva y con quien pasa el mayor tiempo. En el equipo de partnering es quien clarifica los temas y ayuda a los demás a interpretar la filosofía del programa. Será quien revise todos los documentos emitidos y quien deberá aglomerar toda la información.

Es clave que el dueño sea parte de la mesa de partnering pues es quien tiene la relación contractual con todos y quien debe entender la importancia de la rápida toma de decisiones ante los cambios de proyecto que surjan y entender qué partes del proyecto son críticas para el constructor.

El gerente de construcciones es quien debe coordinar las reuniones de partnering. Son quienes luego deben hacer el duro trabajo de llevar a la práctica las decisiones de la mesa, por lo que es quien debe llamar la atención sobre los puntos críticos que va encontrando, transmitiendo sus preocupaciones, pidiendo y proponiendo soluciones.

Los asesores especialistas de las partes mecánicas y los subcontratistas participarán como invitados a las reuniones de VE, donde encuentran a un equipo de base (cliente – arquitecto – constructor) homogéneo, firme en sus convicciones y alineado en sus intereses, lo cual facilita el entendimiento de la problemática de cada instalación específica. Si el subcontratista encuentra fisuras en el equipo de base, ya tiene el camino liberado para iniciar la cadena de incumplimientos.

Es clave que cada parte individual pueda entender las personalidades de las otras partes, para poder trabajar todos juntos. Como una descripción genérica se podría establecer que: El arquitecto es el personaje excéntrico, orgulloso, técnico conocedor y pondrá el máximo esfuerzo en defender su proyecto. Estará callado en las reuniones de partnering, temeroso de abrir una discusión sobre el proyecto y no muy consciente de qué problemas puedan surgir durante el proceso de construcción.

El constructor es el hombre frontal, orgulloso, que conoce el proyecto y está pensando todo el tiempo en cómo obtener una ganancia extra. No le gustan las grandes reuniones y las ve como pérdidas de tiempo. Siempre está involucrado en algún problema y tratará de transferirlo a las otras partes. El buen constructor quiere desarrollar un producto de calidad, pero no se saldrá mucho de lo implícitamente establecido en los pliegos.

El dueño es un personaje escéptico y angustiado. Quiere encontrar el acuerdo entre las otras partes. Espera que el proyectista los proteja del constructor y que el constructor los proteja del proyectista. Quiere que le construyan una joya por 10 centavos en el tiempo previsto y con la calidad especificada.

Las tres partes tienen sus problemas y sus respuestas. El trabajo en un entorno de partnering servirá para encontrar un terreno fértil donde se pueda completar un proyecto exitoso. El trabajo en un ambiente de partnering tratará de revisar sistemáticamente todas las partes del proyecto, para asegurar que el producto final cumpla especificaciones y requisitos del usuario, al costo más bajo posible.

La revisión será continua, no estática, preguntando permanentemente por el *status quo*, sin limitaciones para la creatividad. En la mesa se deben volcar las experiencias anteriores para que los errores no se repitan, dando inicio efectivo a un trabajo de mejora continua.

5. Conclusiones

En el presente escrito se ha tratado de presentar la brecha existente entre los modelos de gestión habituales en el gerenciamiento de proyectos y modelos utilizados en empresas exitosas de distintas industrias. Es importante que cada uno de nosotros haga el ejercicio de medir la brecha entre nuestros conocimientos y actitudes actuales, y los planteados como oportunidad de mejora personal y empresarial.

Luego de leer detenidamente los puntos presentados sintéticamente en los párrafos anteriores, se debe analizar, con un grado severo de autocrítica, cuáles son las técnicas aplicadas en los proyectos en que usted participa y cuáles son los cambios que puede aplicar. El camino a recorrer está dado por la capacitación, la lectura y el análisis de las variables que con forman hoy la industria de la construcción.

La obsesión por la planificación previa de todas las actividades, el fomentar la iniciativa, el seguimiento de los costos, los modelos de asociación, los trabajos en equipo y la honestidad personal e intelectual son los pilares de una gestión de proyectos de alta calidad. Nuestra experiencia nos indica la existencia de una clara correlación entre la aplicación de las mejores prácticas de gestión empresarial con los resultados. Sólo a través de una gestión de alta calidad se logrará construir con la calidad y productividad esperadas.

IMPROVING CONSTRUCTION LOGISTICS

Report of the Strategic Forum for Construction Logistics Group

August 2005

The report ‘Accelerating Change’ published by the Strategic Forum for Construction (SFfC) in September 2002, highlighted that ‘a considerable amount of waste is incurred in the industry as a result of poor logistics’. The SFfC set up a task group, under the chairmanship of Mike Eberlin of Castle Cement, with the support of the Construction Products Association, to research what needed to be done and report on their findings. This report records the group’s findings to date.

There is a lot of opportunity for change. Construction has been slower than other industries to realise the benefits that the application of good logistics can provide. The good news is that we don’t have to make large changes in order to obtain considerable benefits. A lot can be achieved simply through more integrated working. For example, engaging designers early on in the construction process allows them to consider how the components they design might be delivered to site, when the component will be needed and how it will be handled on site. This sort of pre-planning can lead to a substantial reduction in unnecessary transport costs, time wasting, and damage on site. To quote that much over used phrase, ‘it’s not rocket science’!

Change is possible on small as well as larger projects. There is potential for builders’ merchants to expand on their existing business by developing into consolidation centres. Procurement clubs amongst housing associations (where smaller projects are grouped together) are in a good position to improve on how they aggregate logistics across their projects.

These and the other recommendations made by the SFfC Logistics Group have been drawn together in an action plan that is being coordinated by Constructing Excellence in the Built Environment. Progress on the action plan will be reviewed by the SFfC in twelve months time. In the meantime we welcome your feedback on this report which should be sent to Kate Dunne at kdunne@strategicforum.org.uk.

Peter Rogers
Chairman, Strategic Forum for Construction

Improving Construction Logistics

ANALYSIS

Background

The report 'Accelerating Change' published by the Strategic Forum for Construction in September 2002, highlighted that 'a considerable amount of waste is incurred in the industry as a result of poor logistics'. The Forum subsequently identified addressing logistics as one of its priorities and set up a Task Group under the chairmanship of Mike Eberlin of Castle Cement to recommend what needed to be done. The list of the members of the Group is at *Appendix 1*.

The Group did not want to start from scratch in addressing this subject and set out to build on work already undertaken by the Construction Best Practice Programme in its '*Factsheets on Logistics'*, the research '*Construction Logistics: Consolidation Centre'*, and the Constructing Excellence publication *'Construction Logistics: Models for Consolidation'*. Against this background the Group agreed that its terms of reference should be to;

Identify the key issues that need to be addressed to improve logistics in the construction industry

Develop an Action Plan that highlights the steps that need to be undertaken by the different parts of the industry in order to address these issues

Establish means by which the impact of the proposals in the Action Plan can be measured and a resulting improvement in logistics demonstrated

Arising from this, the Group identified 4 key issues on which it chose to focus its attention:

- Design
- Transport
- Stockholding
- More efficient use of on-site labour

The Group 'brainstormed' these four issues and its conclusions were tested at a Workshop hosted by Constructing Excellence and attended by some 30 people from across the construction industry.

What points to Logistics being poor in the Construction Industry?

There is plenty of non-quantified evidence that demonstrates the inadequacy of logistics in the construction process, whilst in other industry sectors there are increasing examples of how they are addressing logistics. This can be illustrated in a number of ways.

- A high proportion of lorries in the construction industry move around the road network either empty or with part-loads, whereas the retail sector and wider manufacturing industry are continually working to consolidate delivery loads to maximise vehicle fill, and reduce transport costs.

- Many lorries arriving at construction sites are having to wait to gain access or be unloaded, whereas retail and other sectors designate time slots for supplier deliveries. Late or early deliveries can be turned away and suppliers charged a penalty.

- In construction, skilled craftsmen are often using their skills for less than 50% of their time on site. Amongst the non-skilled tasks they are involved in are unloading lorries and moving products around site. Other industrial and retail sectors use special equipment to unload lorries and designated trained teams to deal with material handling activities.

- Construction products are often stored on site for long periods of time and have to be moved to other parts of the site when they are eventually needed. Retailers and those in other industries are continually trying to reduce inventories and at least ensure they are held in the most appropriate location. Effort goes into delivering the right quantities at the right time.

- In construction, specialist contractors sometimes arrive on site when they are not expected or when the job is not ready for them. Good manufacturers would ensure they had the right information flows about work progress to ensure this never happened.

- There continues to be much secondary working on site, whereas other industrial sectors make every effort to get it right first time and avoid multiple handling.

- In construction there would appear to be a much higher proportion of damaged and waste product removed from site than in other sectors.

- There is little formal training in logistics and yet there are a large number of tasks that fall within a logistics umbrella. The chart at *Appendix 2* has been prepared by Wilson James to illustrate the point. In many other sectors, training in logistics skills is given much greater priority and some employ those with degrees in the subject.

In summary, other industry sectors, especially manufacturing and retail, have made huge advances in improving logistics, whereas the construction industry does not seem to be taking advantage of these opportunities.

What are the consequences of poor Logistics?

Unnecessary cost in the system

All the evidence highlighted above points to there being additional cost in the system that could be saved if the process operated more efficiently as a result of improved logistics. Research by BSRIA in the 10 years since 2004 has shown that on average 10% of the working day of site operatives in all trades is lost due to waiting for materials, or collecting materials, tools, and equipment. Given that site operations account for about 30% of construction costs, this would suggest that this inefficiency alone is adding about £3billion to the annual cost of construction.

Poor image of the construction industry

Lorries parked in an inconsiderate way outside construction sites whilst waiting to unload does not give the image of an efficient industry. Disorganised sites with skilled craftsmen being used for un-skilled jobs does not encourage quality people to join the industry. Vehicles driving around empty or with part-loads does not convey the image of an industry that has environmental concerns at the top of its agenda, nor does large amounts of waste being removed from site, 85% of which goes to landfill. None of this seems consistent with the growing attention that companies are expected to pay to corporate social responsibility.

Poor quality construction

Working in a disorganised environment will inevitably make the production of quality construction more difficult. Work interrupted whilst materials are sort from elsewhere on site, or delayed whilst products are delivered, will have an adverse effect on quality. Secondary working of products on site is also less likely to provide the same quality of product that could be manufactured in a factory environment.

Increased project time

Most of those features of construction projects that point to poor logistics will add to the time of construction projects. Delays whilst product is unloaded, subsequent movement of products around site and secondary working of product all add unnecessary time that would be eliminated in a well organised project.

Added risks to health and safety

Unnecessary products stored on site inevitably bring with them additional potential hazards. Additional manual handling (either because product is in the wrong part of the site, or because the right equipment is not available) adds to the health risks to those on site. Secondary working of material also brings risks and research has shown that a number of accidents on site occur as a result of workers tripping over discarded material arising from secondary working.

What are the potential benefits from improving Logistics?

The fragmented nature of the construction industry and the lack of transparent costings make it very difficult to estimate exactly what the potential savings would be if all these issues were addressed. There is, however, a widespread belief that substantial savings are achievable, and estimates range from those who believe costs could be reduced by 10%, to those who see savings of up to 30% being achieved.

One well documented case study is the Mid – City Place development in Central London. On this project a strategy was developed to reduce multi-handling and repeated moving of materials. This improved logistics led to some 35% less material waste than benchmark sites, distribution of material with one less pair of hoists, and almost 100% performance in materials being distributed in the right time and place. This all contributed to the project being completed 11 weeks ahead of the planned programme, with a build rate 60% ahead of the industry benchmark, building cost 80% of industry benchmark, and 675,000 hours worked without a single reported accident.

In another case study undertaken as part of the CITB ConstructionSkills research '*Accelerating change through Supply Chain Management'* a programme was developed for delivering 10,000 kitchens.to a housing refurbishment programme on a 'just in time' basis on small trucks rather than in larger volumes with much bigger vehicles. This resulted in a considerable reduction of waste, storage, and double handling of materials. All those involved saw the considerable benefit arising from this, although measuring these benefits has proved more difficult because of the lack of a 'business as normal' model against which to compare the improvements that have been achieved.

Case studies have a part to play in helping to demonstrate the benefits that arise from improved logistics, but the particular circumstances of a project limit, in many people's eyes, the extent to which lessons are transferable. Nevertheless, it is hard to disagree that reduction in transport movements, less money tied up in stock, less waste, and the more efficient use of skilled craftsmen, will reduce the costs of projects, reduce construction time, improve quality, reduce risks to health and safety of those who operate on them, and generally improve the image of the industry. The challenge is to produce the information that convinces all parts of the industry that things need to be done differently in order to improve logistics.

What is preventing the industry from addressing Logistics?

A number of factors of the construction industry prevent it from effectively addressing logistics problem.

- There is no real incentive to tackle this because it is difficult to identify who benefits. Those who may be required to do things differently do not necessarily benefit

- Every construction job is seen as a 'one-off', with a team built up for a short period of time and then disbanded afterwards. It is therefore difficult to engineer the system to optimise logistics in the way that is possible in a manufacturing or retail environment.

- This is further hindered by the fragmented nature of the construction industry with contractual arrangements that get in the way of a holistic approach to things like logistics. Lack of direct employment also hinders this

- Advance planning and design of projects is generally inadequate, as are lead times

- There is a lack of transparency in costs throughout the construction process. Decisions are often based on cash flow. The way costs are recorded does not help identify the potential savings from improved logistics

- Unlike other industries, the information provided in construction is generally an 'estimate' rather than an exact science

- There is a general lack of understanding of the constraints of the supply chain. There is also a lack of trust and confidence that the supply chain will actually deliver when required. Can projects rely on a 'just in time' delivery of products?

- Clients (and others) believe that project cost already allows for appropriate resources to be committed to logistics on the project

The Action Plan which follows attempts to address many of these.

ACTION PLAN

Support for other initiatives that will contribute towards improving logistics.

Development of Integrated Project Teams and Supply Chains

One of the recurring themes in the Group's discussion is that logistics will not be adequately addressed until the construction industry works in a more integrated way, with all parts of the supply chain, including specialist contractors and key manufacturers / suppliers, involved at the outset of projects. The development of integrated teams and supply chains is already a key priority for the Strategic Forum, with a target that 50% of projects by value are undertaken in an integrated way by the end of 2007. In terms of improving logistics, a more integrated approach will help break down the barriers that the current contractual relationships impose and help encourage greater cost transparency on projects. The Group is therefore keen to see this integrated approach to projects developed as quickly as possible and welcomes the recent National Audit Office Report *'Improving Public Services through better construction'* which highlights the benefits to be gained from this.

Off – site manufacture and Modern Methods of Construction

One of the reasons why logistics is so important in construction is the fragmented nature of the industry and the wide range of products and systems that need to be put together, invariably in an unpredictable outside environment. The increasing attention that is being given to off-site manufacture and modern methods of construction is helping to reduce the number of individual products that need to be delivered to, and assembled on site.

Whilst in some respects this is helping to make the logistics on a project easier, the importance of good logistics is even greater if the benefits that these new systems have to offer in terms of productivity on site are to be achieved. The Group is therefore keen to see that organisations such as BuildoffSite and the Housing Forum, which are highlighting the benefits of off-site manufacture and modern methods of construction, ensure proper attention is given to logistics on the projects where such systems are used.

Programme for improving logistics

No one part of the construction industry can deliver improved logistics on its own. The benefits will come from the different parts of the industry inter-acting in a different way – planning together, sharing information, and exposing the real cost of activities in a way that is currently not typical. In order to bring about this change, the Group has identified the contribution that it wants to see each part of the industry make, not because it wants to see the different parts of the industry working in isolation, but because it is the easier way to hold each sector responsible for bringing about change.

1. Clients

Clients have every reason to expect the supply side to deliver their projects efficiently and to ensure that proper attention is given to logistics so that the benefits referred to earlier are delivered. Clients can help in this by making clear to those they appoint that they expect them to prepare a Logistics Plan at an early stage in their projects, and that all the key players in the supply chain have signed up to this Plan.

The Group would, therefore, like to see:

- *The Client's Charter refer to the expectation that a Logistics Plan is prepared at an early stage in every project*
- *A Best Practice Guide prepared to help clients understand what they can expect from the supply side on logistics*

2. Design Professionals

Design Professionals need to be more aware of the part they play in ensuring good logistics, particularly at the scheme design stage. Logistics will be greatly helped if the design professionals draw up a Process Map at an early stage in the design. In addition as part of the Logistics Plan for the project, a Bill of Materials should be prepared. This should look at, for example, the flow of materials needed on a project and ways of minimising stockholding. Which of the professional members of the supply chain should be responsible for this, needs to be discussed, but the quantity surveyors with their background in measurement and costing might have the appropriate skills for this; alternatively it could require the input of logistics specialists. Manufacturers, suppliers and distributors clearly need to make an input to this Plan.

The various professional bodies responsible for the design professions in the construction industry – RIBA, ICE, IStruct E, and CIBSE on design issues, and RICS on measurement and costing– are in the best position to highlight the importance of logistics to their current membership as well as in the training of those seeking to join the profession. In the short term this can be achieved through awareness guidance as part

of continuing professional development. In the medium term, the importance of logistics needs to feature in the initial education and training of those preparing for a career in one of the construction professions.

The Group would, therefore, like to see:

- *Design professionals prepare a Process Map for each project as part of the Scheme Design*
- *The professional institutions representing the design professions develop advice and offer briefing to members on the role they have to play in project logistics*
- *The professional team needs to prepare a Bill of Materials as part of the Logistics Plan*
- *The professional institutions consider ways in which the role of their profession in project logistics can be incorporated in initial education and training.*

3. Main Contractors and specialist contractors

Many see the construction manager as the key player in co-ordinating the logistics on a construction project, but the conclusions reached earlier suggest this is not a function that is being carried out as effectively as it should be across the construction industry. As a result, logistics specialists are being involved in some of the major projects. Irrespective of who carries it out, the responsibility for project logistics must rest with the main contractors, and it is essential they drew up a Logistics Plan in consultation with the rest of the supply chain at the outset of a project. The Bill of Materials will be an important input to this and the specialist contractors should each prepare that sub-set of the Logistics Plan relevant to their specialist input including how they will be making optimum use of the skilled labour on site.

Those responsible for the logistics on a project must have the right skills to perform the function and CITB Construction Skills is asked to recommend how logistics skills can be developed in the industry.

The Group would, therefore, like to see:

- *Main contractors prepare a Logistics Plan in consultation with the rest of the Supply Chain at the outset of each project. This Plan should include the input to the project from the specialist contractors and the key manufacturers and suppliers.*

- *CITB Construction Skills review the need for logistics skills in the industry and recommend what needs to be done to address this.*

4. Manufacturers, Suppliers, and Distributors

A key part of logistics for a construction project is to ensure that the products and materials arrive on site at the time and in the quantities that are required. This does not just depend on the efficiency of the supply network, but it also relies on the pre-planning of those on the construction site, as well as the quality of the communication between those planning the project and those supplying the products and materials. Manufacturers and suppliers can make a significant contribution to the efficiency of the logistics on a project if they are involved early enough in the process and, in particular, if they can make an input to the Logistics Plan through the preparation of the Bill of Materials.

On the transport side, there may be an opportunity to look at ways of developing best practice and learning from other industries through the Department for Transport's Sustainable Distribution .programme. This has not so far given any attention to construction and it is hoped that the Department can be persuaded to remedy this.

As part of its wish to see greater transparency of cost in the construction process, the Group would like to see manufacturers and suppliers reflect the true cost of distribution in their pricing policies.

The development of the Consolidation Centre at Heathrow Airport was an innovative approach to the particular challenges faced by working in that kind of environment. For a variety of reasons, this particular approach is not applicable throughout the industry, but there may be lessons for the way products are supplied to other large projects. Manufacturers and suppliers are encouraged to see what these lessons might be.

The Group would, therefore, like to see:

- *The Department for Transport's Sustainable Distribution programme include work on transport in the construction industry.*
- *Key manufacturers, suppliers, and distributors input to the Bill of Materials being prepared as part of the Logistics Plan for each project*
- *Manufacturers, suppliers, and distributors reflect the cost of distribution in their pricing policies*
- *Manufacturers, suppliers, and distributors work with contractors to see how lessons from the Consolidation Centre approach might be transferred to other significant construction projects and programmes*

5. Information Technology

The Group did not believe that the industry was using electronic communications as effectively as other industries were to help in improving logistics throughout the supply chain. In particular, the industry was not utilising bar coding for product ordering, or E-tagging for tracing products throughout the process, to the extent that seemed appropriate. A case study was being developed as part of a CITB ConstructionSkills research project in order to trial bar coding on the panes of glass required on a major project. Unfortunately, the case study could not be completed because of the difficulty of co-ordinating those parts of supply chain involved in this – manufacturers, distributors, main contractors and specialist contractors. This is symptomatic of many of the difficulties in the industry, and the Group would, therefore, like to see further case studies developed to address these difficulties and to demonstrate the benefit that bar coding has to offer.

In the time available to the Group, they were not able to look into the issue of information technology to the extent they would have liked. They are convinced, however, that there is much the industry could do to take advantage of these new technologies in a way that will make a significant input to improving logistics. This needs much more consideration and it is felt that some of the DTI programmes focusing on wider use of IT should be able to help in this.

The Group would, therefore, like to see:

- *The industry work with DTI to focus part of that Department's work on information technology towards the way this can be used to help improve logistics in the construction industry.*

- *As part of this programme, two case studies developed to show the potential benefits of bar coding. These case studies should each focus on a specific product being used on a major project.*

6. Case Studies

Members of the Group and those who attended the workshop were keen to see case studies developed to help demonstrate the benefits that can arise from improved logistics. Previous case studies such as Mid – City Place and the Heathrow Consolidation Centre have helped to demonstrate what can be achieved when specific attention is paid to logistics, and a suggested case study on the wider potential for bar coding is put forward in an earlier section of this Action Plan.

What the Group would, therefore, like to see is:

- *The development of a 'model project' to help understand the information flows that are needed to create an efficient Logistics Plan and address the existing shortcomings on logistics in construction projects..*

- *Some sector / product specific case studies showing how the logistics surrounding the supply of certain products can be improved. This would include, for example, establishing what information is needed at the outset of projects to allow manufacturers to organise better the supply of their products. The mechanical and engineering sector was one where the Group felt that such a case study might be particularly appropriate.*

7. Learning from other industries.

Earlier in the report, comparison was made between the construction industry and the progress that has been made towards improving logistics in other industry sectors. There is clearly much that construction can learn from the way other industries approach logistics and it is hoped that in taking forward various of the proposals identified earlier, those responsible will, where appropriate, seek to tap into the experience of other industries on these issues. One particular project funded by the EPSRC is being undertaken at Cardiff Business School and is looking at *'Mass, Customised, and Collaborative Logistics'.* The sectors being studied as part of this project are steel, retail, and construction. The researchers see a common interest in many of the messages emerging from this work for the Strategic Forum and would like to see how they can help take this forward.

Taking the Action Plan forward

A summary of these actions with an indication as to who should be responsible for taking them forward is attached at *Appendix 3*. To ensure progress is monitored, there needs to be a single point of responsibility for co-ordinating the follow up to this report and the Group recommends that this should be taken on by Constructing Excellence in the Built Environment with the appropriate input from each member of the Strategic Forum. A report should then be presented to the Strategic Forum in the spring of 2006 on the progress that has been made in taking forward the Action Plan.

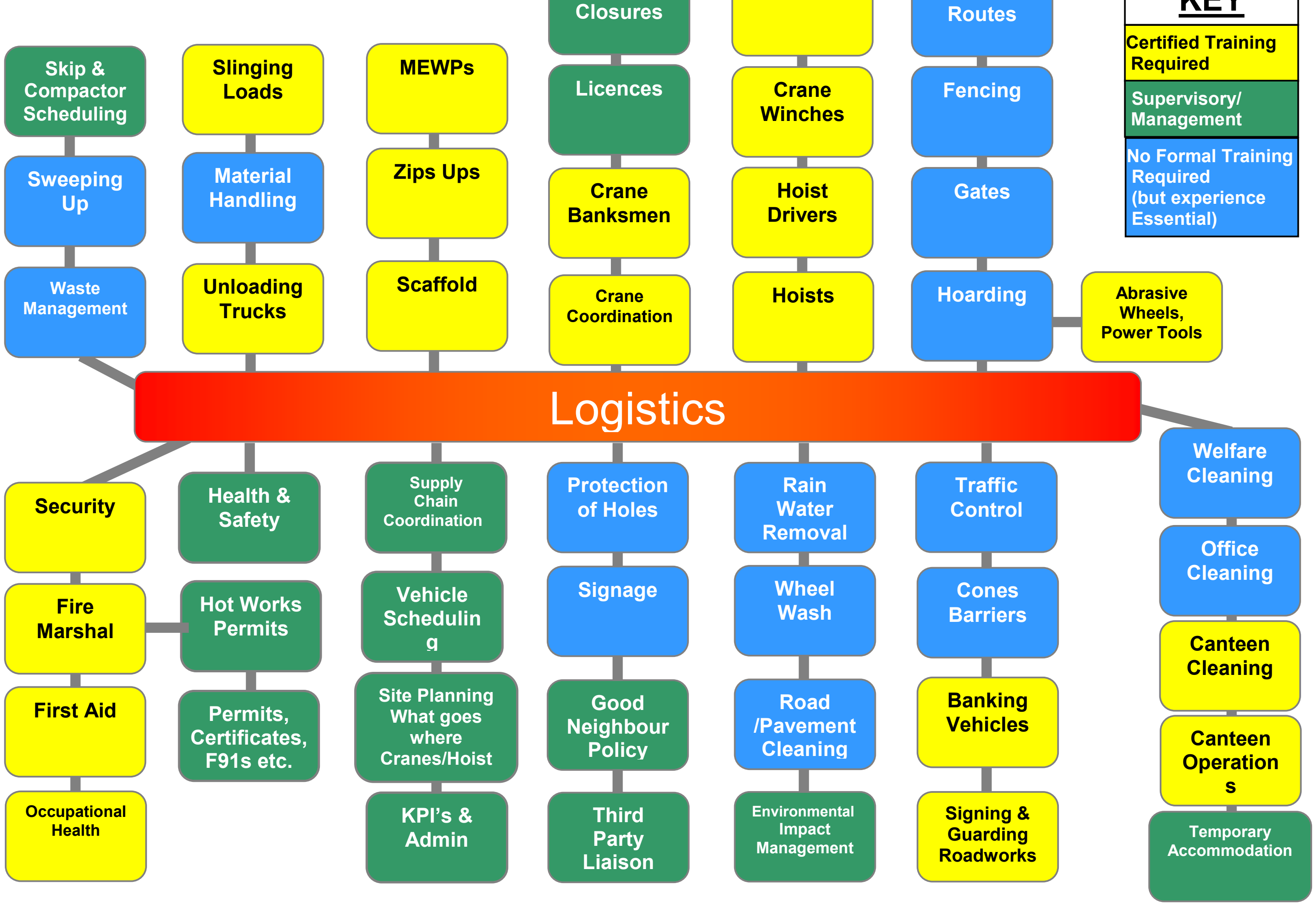
Appendix 1 Members of the Strategic Forum Logistics Task Force

Chairman	Mike Eberlin	Castle Cement
Members	Rick Ballard	The Logistics Business
	John Brooks	MACE
	John Connaughton	Davis Langdon Consultancy
	Chris Ctori	BAA
	Paul Fenlon	NHS Estates
	John Hobson	Management of Change
	Phil Holden	Pascall and Watson
	Mike Holley	Excel
	Gary Sullivan	Wilson James
	Michael Ankers	Construction Products Association
Secretary	Kate Dunne	Strategic Forum for Construction

The Group also received support from Brian Moone and Ian Pannell when they were part of the Constructing Excellence team

Appendix 2

Required Certification for Logistics



Appendix 3

SUMMARY OF ACTION PLAN

Action Directed to	Action Required	Lead Organisation (s)
Clients	• *Client's Charter to refer to the expectation that a Logistics Plan is prepared at an early stage in every project* • *Best Practice Guide to be prepared to help clients understand what they can expect from the supply side on logistics*	Construction Client's Group Construction Client's Group in co-operation with other umbrella bodies on Strategic Form
Design Professionals	• *Design professionals to prepare a Process Map for each project as part of the Scheme Design* • *Professional institutions representing the design professions to develop advice and offer briefing to members on the role they have to play in project logistics* • *Professional institutions to consider ways in which the role of their profession in project logistics can be incorporated in initial education and training.* • *Professional team prepare a Bill of Materials as part of the logistics plan.*	CIC in Partnership with RIBA, ICE, IStructE, and CIBSE
Main Contractors and Specialist Contractors	• *Main contractors to prepare a Logistics Plan in consultation with the rest of the Supply Chain, at the outset of each project.* • *CITB ConstructionSkills to review the need for logistics skills in the industry and recommend what needs to be done to address this.*	Construction Confederation in co-operation with Construction Products Association, National Specialist Contractors Council and Specialist Engineering Contractors Group CITB ConstructionSkills in co-operation with Summit Skills and with support of Construction Confederation, NSCC and SEC Group

Manufacturers and Suppliers	• *Department for Transport's Sustainable Distribution programme to include work on transport in the construction industry.* • *Key manufacturers and suppliers to input to a Bill of Materials as part of the Logistics Plan for each project* • *Manufacturers, suppliers and distributors to reflect the cost of distribution in their pricing policies* • *Manufacturers, suppliers and distributors to work with contractors to see how lessons from the Consolidation Centre approach might be transferred to other significant construction projects and programmes*	Department for Transport Construction Products Association Construction Products Association Construction Products Association together with Construction Confederation, NSCC and SEC Group
Whole Industry – Information Technology	• *The industry work with DTI to focus part of that Department's work on information technology towards the way this can be used to help improve logistics in the construction industry.* • *As part of this programme two case studies developed to show the potential benefits of bar coding. These case studies should each focus on a specific product being used on a major project.*	Constructing Excellence and DTI with support from other Strategic Forum umbrella bodies. Constructing Products Association, DTI and Construction Excellence with support from other Strategic Forum umbrella bodies
– Case Studies	• *The development of a 'model project' to help understand the information flows that are needed to create an efficient Logistics Plan and address the existing shortcomings on logistics.* • *Sector / product specific case studies showing how the logistics surrounding the supply of certain products can be improved.*	Construction Excellence with support from other Strategic Forum umbrella bodies and possible event sponsorship from one of the industry journals. Construction Products Association / manufacturing sector trade associations in partnership with Construction Confederation and specialist contractor associations
– Learning from other industries	• *The industry work with Cardiff Business School as part of their 'Mass, Customised, and Collaborative Logistics' Project to see what lessons can be learnt from other industries*	Constructing Excellence with support from other umbrella bodies on Strategic Forum

INDUSTRIALIZATION OF CONSTRUCTION – A LEAN MODULAR APPROACH

Anders. Björnfot[1] and Lars Stehn[2]

ABSTRACT

The concept of industrialization and lean thinking in construction has drawn quite a bit of interest in recent years. Authors have recently begun to critically debate the direct implementation of lean thinking in construction; instead the focus should be related to transformation, flow, and value. This paper is based on a literature review of modularity, lean construction, and buildability. Modularity is then extended to the production phase where simulated assembly scenarios are used to explore and exemplify modular effects during production of long-span timber structures. The literature review suggests that modularity is related to product management, with process management effects, while lean thinking is a process management principle. Both principles are focused on the creation of buildability which is argued to be more of a goal than a means of efficiency. The simulation scenarios indicate possible modular benefits associated with, e.g., organization, out-sourcing, pre-assembly, prefabrication, and development. Modularity is thus argued to advocate management of production in the form of lean construction. The focus for timber construction should be on modularity; i.e., a bottom-up product focused view enabling product value. Such a view has potential to be a driving force in the struggle for industrialization in construction.

KEY WORDS

Assembly, buildability, constructability, industrialized construction, lean thinking, modularity, production, timber structures.

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INTRODUCTION

Industrialization can be seen as a structural means for eliminating, or at least drastically reducing, on-site activities in construction (Koskela, 2003). Industrialization is thus a streamlined process promoting efficiency and economic profit. Regarding the goal of industrialization, there is a wide variety of literature considering the industrialization approach in construction, e.g., supply chain management (London and Kenley, 2001; Naim and Barlow, 2003), lean construction (Gann, 1996; Crowley, 1998), buildability (Poh and Chen, 1998), scheduling (Austin et al., 2000), re-engineering (Winch, 2003), and standardization/prefabrication (Dawood, 1996; Gibb, 2001). Two main principles aiming for industrialization are found in the construction literature above; lean construction and buildability. A third main principle, modularity, is a key issue in the engineering management literature applicable to the manufacturing industry.

In the manufacturing industry modularity has been shown to reduce the number of suppliers from thousands to a few hundred (Crowley, 1998). A good example of industrial success is Volvo Corporation, where the integrated modularity has been guiding the company's transformation (Kusiak, 2002). Modularity is said to be a key concept in the manufacturing industry and has helped lead the way towards widespread industrialization (Gann, 1996). In Björnfot and Stehn (2004) it was argued that industrialization for the construction industry should be linked with modularity, incorporating both prefabricated and standardized products.

The concept of lean construction is concerned with the application of lean thinking in construction (Green, 1999). Authors have recently begun to critically debate the direct implementation of lean thinking in construction (Green, 1999; Naim and Barlow, 2003; Winch, 2003). Reengineering of construction should, instead of applying the whole lean paradigm, focus on its foundation, i.e., transformation, flow, and value (Koskela, 2003). A third principle mentioned together with industrialization in construction is buildability. Buildability has been focused on a wide variety of tasks in construction, e.g., production methods (Fischer and Tatum, 1997), the construction process (Griffith, 1986), and organization of production (Stewart, 1989; Ferguson, 1989). In lean construction, organization of production is termed as work structuring (Ballard et al., 2001).

In Björnfot and Stehn (2004) it was shown how product modularity can guide the design process for long-span timber structures, aiding in the design and providing guidance in optimization problems. Modularity also confers process related effects and can thus ease the implementations of lean construction principles. The motive for the research presented in this paper is to show how modularity in construction can be utilized for an efficient industrialization of construction. The aim of this paper is to explore the industrialization principles; modularity, lean construction, and buildability by attempting to understand their relations and implications on construction. The construction process is in this paper regarded as the transformation process, i.e. flow of information and material in design and production respectively. As simplifications, no analysis is performed of the construction process or its flows, and product value is considered to be a vital part of the value for construction as a whole, without any deeper analysis of its implication. Effects of modularity in construction is finally explored and exemplified by simulating possible assembly scenarios for long-span timber structures, using current production practices. The empirical data used for the simulations is based on a case-study performed at a Swedish design company.

INDUSTRIALIZATION PRINCIPLES AND THEIR RELATIONS

Paramount to this paper is the construction industry and the conventional "design & build process" (D&B), Figure 1. The process description is based on Swedish conditions and used during construction of long-span timber structures. The explored industrialization principles are related and linked together using the different phases of the construction process. The case study is used to in practice explore the implication of modularity in construction and specifically, its relations to lean construction and buildability.

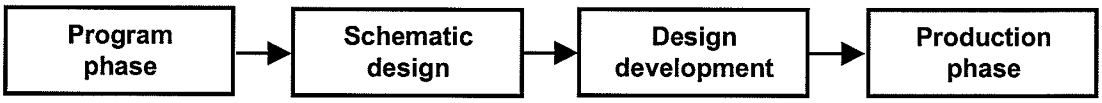

Figure 1: The considered construction process.

MODULARITY

Modularity in construction has frequently been viewed as the use of simple building blocks (Rampersad, 1996), or volumetric pre-assemblies (Murtaza et al., 1993; Dawood, 1996). Today, the sense of the term module has evolved so that a module contains the specifications of a building block and interfaces, as well as considerable functionality compared to the end product (Miller and Elgård, 1998). Based on this definition, the volumetric pre-assemblies are a number of modules fitted together into volumes. The volume is thus a form of modularity, which is a system attribute (Miller and Elgård, 1998). Modularity can therefore not be defined from the modules themselves instead modularity is related to product structure and functionality, and should be used considering the products whole lifecycle (Nørgaard, 2002).

One of the most important aspects of modular products and their realisation is the potential for efficient flexibility and responsive manufacturing through flexibility/agility (Marshall and Leaney, 1999), and reduced process complexity (Marshall et al., 1999). The term mass customization is often mentioned together with flexibility and argued to be a key aspect of modularity (Marshall et al., 1999). The basic drivers behind the wish for modularity, Table 1, are found in (Blackenfelt, 2001) summing up the drivers given in (Miller and Elgård, 1998; Marshall and Leaney, 1999). Nørgaard (2002) uses the product lifecycle when sorting module drivers; however the drivers are basically the same.

Table 1: The module drivers and their relation to the three main problems approached by modularity.

Module drivers		
Commonality Variety Internally planed change Externally driven change Upgradeability Addability Reconfigureability	Concentration of risk Separate development Parallel development Pre-assembly Separate testing Out-sourcing (buy) In-sourcing (make)	Repair Replenishment Component reuse Material recycling Incineration Landfill
Variety versus commonality	**Organization of development and production**	**After sale of product**

In the literature, measured quantitative effects of modularity in construction are rare. There are clearly effects of modularity that are difficult to measure in quantitative terms, i.e. variety and complexity as well as process related effects in development, manufacturing, and production. Murtaza et al. (1993) report construction phase cost savings of 10 % using modularity and Gotlieb et al. (2001) report schedule and cost savings of up to 25 %.

The literature review suggests that modularity is both a product and process attribute, and should be developed by a linked methodology (Marshall et al., 1999). The modular process covers all the modularity effects in the product value-chain; only by performing product modularity can the benefits be realized. For the construction process;

- **Variety** through modularity aims at the reduction of internal complexity and increased external variety, i.e., provide a means for an open building system.
- **Development** aims at the development of new modules for increased external variety. In construction this can emerge as out-sourcing of modules for increased supplier competitiveness or development of multi-functional modules.
- **Production** aims at the design and use of products in such a way that a streamlined production can be achieved.
- **After-sale** aims at the use of modules after structure lifetime, disassembly and recycling of modules as well as extension of structure lifetime by reconfiguring.

THE LEAN METHODOLOGY

The primary goal of the lean concept is the elimination of waste or in other terms, creation of value (Green, 1999). Lean thinking concentrates on the two main conversion activities; design and construction, where information and material flows are the basic units of analysis (Crowley, 1998) - "*lean thinking concentrates on going into the "black box" and studying the processes with the objective of smoothing out interfaces, removing non-value adding activities, or in some cases completely rebuilding the processes and generating new* *processes*" (Halpin and Kueckmann, 2002). The basic purpose of lean thinking is thus the management of conversion processes to promote flow, figure 2.

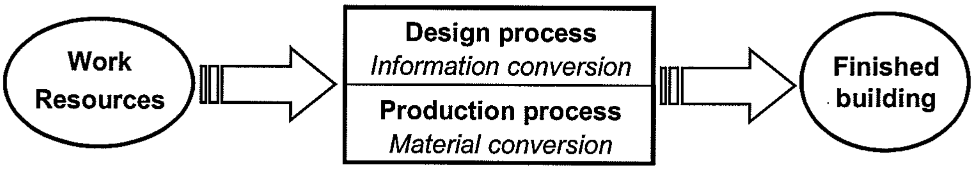

Figure 2: In construction, the lean concept is the management of the conversion process.

The main practices of lean thinking most often referred to in the literature is; just-in-time (JIT) and total quality management (TQM) (Gann, 1996; Green, 1999; Halpin and Kueckmann, 2002). The practices, total preventive maintenance (TPM) and human resource management (HRM) were added by Shah and Ward (2003). A literature survey by Shah and Ward (2003) identified a number of key practices associated with JIT, TQM, TPM, and HRM summing up the above key characteristics, Table 2.

In construction the information conversion process may be related to design development while the material conversion process is associated with production. For the application of leanness in construction (e.g., Ballard et al., 2001; Bertelsen and Koskela, 2002; Koskela, 2003) it is argued that construction should be based on; maximizing value, minimizing waste, and the transformation of inputs into outputs. Lean construction is thus a methodology aiming at streamlining the whole construction process while product requirements are realized during design, development and assembly. The solutions to the value/waste generation proposed in e.g. Ballard et al. (2001) incorporates many of the concepts from the lean practices, Table 2, the modular practices, Table 1, and further many arguments based on the concept of buildability/constructability.

Table 2: Key lean practices in JIT, TQM, TPM, and HRM (adopted from Shah and Ward, 2003).

Key lean practices			
Lot size reduction	Preventive maintenance	Benchmarking	Self-directed teams
Continuous flow	Maintenance optimizat.	Quality programs	Flexible workforce
Cellular manufacture.	Safety improvement	Quality management	
Bottleneck removal	Scheduling strategies	Process measure.	
Reengineering	New equip./technology	Cont. improvement	
JIT	**TPM**	**TQM**	**HRM**

BUILDABILITY/CONSTRUCTABILITY

The terms buildability (European term) and constructability (American term) both describe a similar area of interest in construction (e.g., Griffith, 1986; Tatum et al., 1986; Fischer and Tatum, 1997). The definitions of buildability found in the literature are most often concerned with the design of the building, i.e., the most common definition; "*the extent to which the design of a building facilitates ease of construction, subject to the overall requirements for* *the completed building*" (Griffith, 1986; Poh and Chen, 1998). This definition suggests that there is more to buildability than the product which also Griffith (1986) observes, linking both technical and managerial aspects to buildability.

An interesting connection is the relation between buildability and manufacturability, the design for assembly (DFA), and the design for manufacturing (DFM) methodologies. Manufacturability can be seen as buildability in manufacturing (Sharma and Gao, 2002). DFA and DFM, are methodologies aiming at reduced complexity in assembly, and reduced assembly costs; therefore their relationships to modularity is strong (Rampersad, 1996). Based on the above definitions it is not unlikely that buildability has its origins in the manufacturing industry. The relationship between the three methodologies and the diversity in their definitions does not provide any clear guidance on what buildability really is, as an example; buildability has also been associated with quality (Pheng and Abeyegoonasekera, 2001). Though, it is clear that buildability has a distinct relationship to productivity. This relationship is not fresh. For example, Poh and Chen (1998) describe a method for evaluation of buildability aimed at an increased productivity.

The main argument in the buildability literature is the use of standardization and prefabrication for increased buildability (Stewart, 1989; Ferguson, 1989; Poh and Chen, 1998). Prefabrication and standardization have advantages as well as disadvantages (Bock, 2001). Even though both standardization and prefabrication are important for an industrialization of construction, they will by themselves not revolutionize construction; instead they should be seen as an effect of the buildability approach.

SUMMARY AND CONCLUSION

The differences found between the three disciplines can be argued to be minimal and their goals the same, i.e., an industrialization of construction. Many authors also seem to mix the principles. Table 3 illustrates the applications of the three principles for the construction process based on the similarities and differences summarized as:

- **Modularity** is both a process and a product discipline offering a wide variety of advantages in the whole construction process. In construction, modularity is applied at the product level and realized in design development and production.
- **Lean construction** is a process management discipline offering management during the whole construction process, aiming at streamlining production.
- **Buildability** is a process and product based principle. In contrary to modularity; buildability is more of a goal than a means for product and process efficiency.

Table 3: The application of modularity, lean construction and buildability in the construction process.

Methodology	Used in...		Provides effects in...
MODULARITY	*Schematic design*	→	*Design development*
	Design development	→	*Production*
LEAN CONSTRUCTION	*Program phase*	→	*Schematic design*
	Schematic design	→	*Design development*
	Design development	→	*Production*
BUILDABILITY	*Schematic design*	→	*Design development*
	Design development	→	*Production*

Based on the literature review and the summarization we argue that the following four characteristics are the core of industrialization in construction, Figure 3;

- the **effects** provided by product modularity promotes buildable designs,
- the **use** of the lean construction philosophy promotes a buildable process,
- lean construction advocates, but **does not** necessarily promote, modularity, while
- product modularity **does** promote a lean construction process.

Two ways of viewing the construction process is top-down or bottom-up (Figure 3). The majority of recent production and construction literature in this area is concerned with streamlining processes, i.e. the implementation of lean thinking which emits a top-down view on construction. In the mechanical industry products are often tailored towards the end customer while the production is volume based. The production of new products is also often based on previous products, enabling reuse of previous technologies and processes. Economic profit in the mechanical industry is therefore based on streamlining processes and enabling their reuse, i.e., a top-down view. In contrary to the mechanical industry, the construction industry is project based with single product production where every structure is viewed as unique and tailored to the end client. The construction industry, and its reuse of technology, can be compared to the design of new products in the mechanical industry, but due to the project based site production the characteristics of the production system may change, causing new problems to emerge (Koskela, 2003). Therefore we, in this paper, argue that the timber construction industry should emit a bottom-up view where the design of the product guides the production processes, i.e., value (or buildability) for the product in design is a requirement for overall product and process value, and in the end; a requirement for end costumer value. Product modularity has in theory been shown to provide many process based benefits; we further argue that modularity is a key concept in the struggle for industrialization in timber construction, and possibly for construction in general.

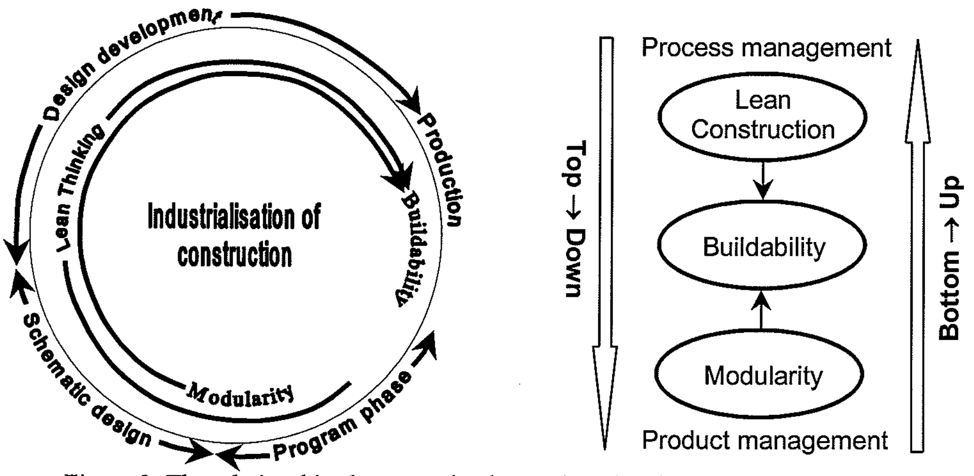

Figure 3: The relationships between the three principles (left) and the top-down vs. bottom-up views in construction (right)

RESEARCH METHOD – CASE STUDY

The case study is based on two phases: interviews and a theoretical survey of the production of long-span timber structures. The case company has three employees and has been competing in the Scandinavian construction market since 1986. The company focuses on long-span structures, offering design and assembly of the structural system. The managing director (MD) has 30 years of experience as a designer. The MD was interviewed with the aim of collecting general information about the assembly operations during the production of long-span timber structures. Long span timber structures were chosen for the easy to comprehend structural system and the straight-forward assembly process. The survey is based on a general type of long-span timber structure used for ice hockey. The aim of the survey was to collect core quantitative production knowledge and experience relating to the case company production practices. The production was studied by reviewing time schedules, quality control plans, drawings, and other documents of interest as well as a rich supply of photographs.

THE GENERAL LONG-SPAN TIMBER STRUCTURE

The specific long-span timber structure, width and length, 36×65 m^2 (118×213 sq. feet), considered in this paper was constructed in southern Sweden during 2003. All quantitative data was compared to the MD´s broad and general knowledge of the production of hundreds of similar structures. The described assembly process can thus be argued as a general process for the production of long-span timber structures in Sweden. The considered structural design is shown in Figure 4.

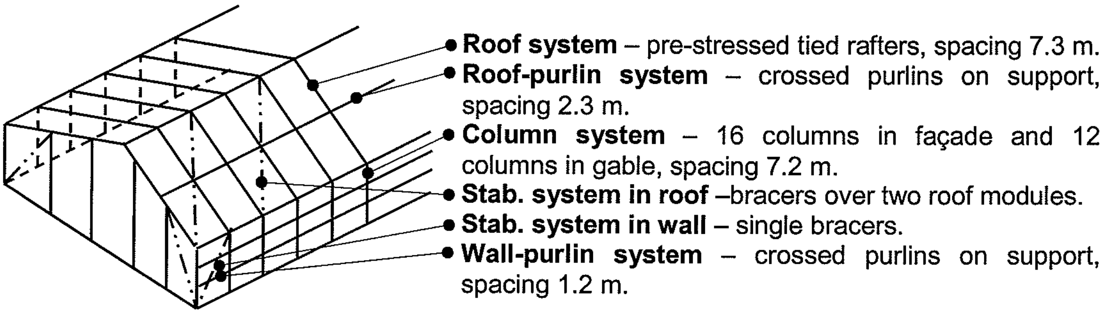

Figure 4: The sub-systems used in this case study

RESULTS FROM THE CASE STUDY

In production there are two general types of resources used; workforce (labor) and machinery (equipment). For long-span timber structures the machinery used are tower cranes and sky-lifts, Figure 5 (picture 4 and 5). The activities during production are divided into three stages. *Sub-assembly* is the activity in which the elements are assembled into a finished module. *Placement* is the activity in which the module, or its constituent elements, is moved on the construction site. *Final assembly* is the activity in which the module is connected to other modules within the structure.

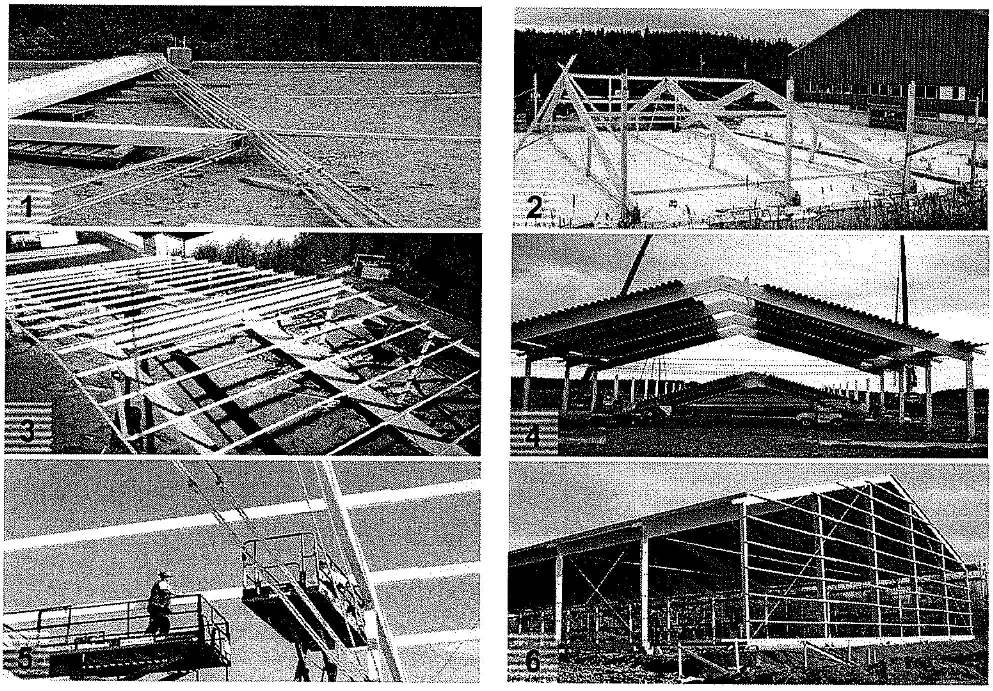

Figure 5: Illustration of the assembly process for long-span timber structures.

THE ASSEMBLY PROCESS FOR LONG-SPAN TIMBER STRUCTURES

In general, the assembly process of the structural system for long-span timber structures takes four weeks. The current sequential assembly process is presented in Table 4. The foundation is cast in place by a separate contractor prior to the start of the assembly. In Table 4, *Sub-system* denote the sub-system being worked on, *Activities* denote the activity performed, *Resources* denote the resources used, and *Time* denote the elapsed time.

Table 4: The sequential assembly process for long-span timber structures.

	Description	Sub-system	Activities	Resources	Time
1 ↓	Set up on site. All required material is delivered to the site on day one.	(set up)	Set up	3 men 1 tower crane	1 day
2 ↓	Organisation of materials; beams, bracers, steel details, etc., Figure 5 (1).	All	Placement	3 men 1 tower crane	1 day
3 ↓	Sub-assembly of roof modules on ground, Figure 5 (1).	Roof	Sub-assembly	3 men	4 days
4 ↓	Sub-assembly, placement, and final assembly of façade columns, Figure 5 (2).	Column	Sub-assembly Placement Final assembly	3 men 1 tower crane 1 sky-lift	1 day
5 ↓	Lift up and temporary bracing of roof modules on ground, Figure 5 (2).	Roof	Placement	3 men 1 tower crane 1 sky-lift	2 days
6 ↓	Preparation of final assembly with roof "packages", Figure 5 (3).	Roof-purlin Stab. in roof	Sub-assembly Placement Final assembly	3 men 1 tower crane 1 sky-lift	3 days
7 ↓	Placement and final assembly of roof "packages", Figure 5 (4).	Roof	Placement Final assembly	3 men 2 tower cranes 2 sky-lifts	1 day
8 ↓	Sub-assembly, placement, and final assembly of gable columns and gable beam.	Column	Sub-assembly Placement Final assembly	3 men 1 tower crane 2 sky-lifts	1 days
9 ↓	Complementary assembly of roof-ridges and stab. in roof, Figure 5 (5).	Roof-purlin Stab. in roof	Sub-assembly Placement Final assembly	2 men 2 sky-lifts	2 days
10 ↓	Assembly of the stab. in façade and gable, Figure 5 (6).	Stab. in wall	Sub-assembly Placement Final assembly	2 men 2 sky-lifts	1 day
11	Assembly of wall-purlins, Figure 5 (6).	Wall-purlin	Sub-assembly Placement Final assembly	2 men 2 sky-lifts	3 days

ANALYSIS AND SIMULATION

The first two days during assembly are generally required for set up on site, unloading of materials, and organization of workforce and materials. The step-by-step assembly process in Table 4 indicates a sequential type of production. Viewing the sub-systems as natural modules in the traditional step-wise assembly process has many potential advantages. Detailed time schedules based on modules and activities may be created by ordering the assembly process after modules (Figure 6). The time schedule is created by performing a day-by-day study of Table 4 and taking note of the current sub-system under work and the activity performed. The time schedule should be read row-wise, i.e., each row contains information about the required activities and time spent on each sub-system. The resources required for each activity can then be obtained from Table 4, e.g., the sub-assembly of the roof system requires four days during which three men are occupied (step 3 in Table 4). Simulations, using the time schedule, of probable scenarios during the assembly of long-span timber structures are used to exemplify the possible effects of modularity in construction and how modularity can confer both construction leanness and buildability.

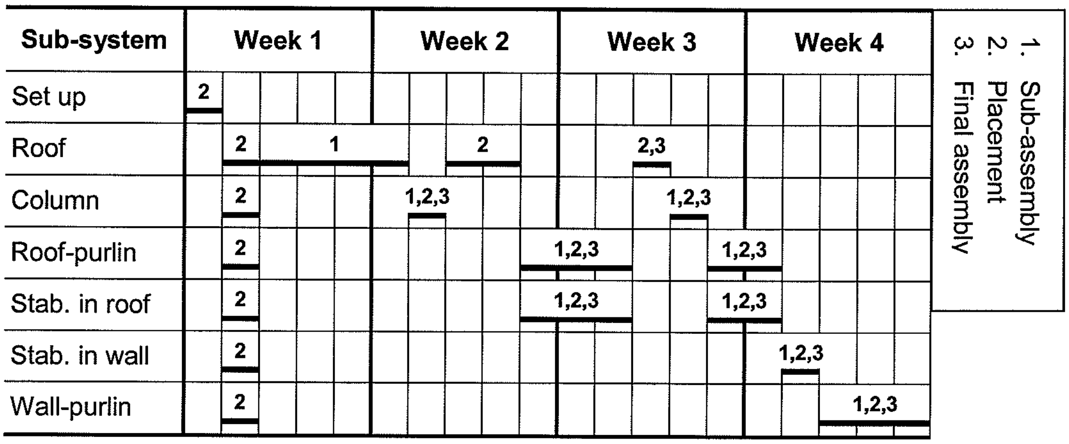

Figure 6: Time schedule sorted by modules, based on Table 4.

- **Set up**. Some components of the roof module are misplaced or were never delivered. Time schedule loss is incurred and one tower crane which has to be on site from day one is left idle (step 1 and 2 in Table 4). *By having each component checked and attached to a module the chance of misplacing items and thereby incurring delays is reduced.*
- **Roof module**. During design, considering the time schedule, it is decided to out-source the roof module for design, manufacturing, and sub-assembly enabling supplier competitiveness and possible cost savings in the program phase. In assembly, the prefabrication of the roof module result in time schedule savings of four days (step 3 in table 4). The cost savings in site production can also be compared with partial prefabrication and on-site pre-assembly. *By the modular approach issues like out-sourcing, pre-assembly, and prefabrication can be used and analyzed in a new light enabling both time and cost savings.*

- **Column module**. The columns are delivered to the site with steel details attached. The sub-assembly part of the column modules is therefore reduced and the time and resource savings incurred can instead be used to work on the placement of the roof system (in Figure 6; work is reallocated from the column to roof during week 2). *A modular approach can enable the reallocation of resources on the construction site.*
- **Roof-purlin module**. A new connector innovation is developed with plug-and-play characteristics, resulting in rapid final assembly. This reduces the overall time required for assembly of the roof "packages" as well as the complementary assembly of the module resulting in time and resource savings. *A modular approach may further streamline the assembly by the development innovations.*

Similar scenarios may be created for the other sub-systems. Possible effects of a modular approach; organization, out-sourcing, pre-assembly, prefabrication, and development, are all ways of streamlining production - a way towards an industrialization of construction.

CONCLUSIONS

The goal of industrialization in construction is the reduction of on-site activities (Koskela, 2003). As shown during the simulations, one of the benefits of modularity is the reduced complexity in choosing whether to remove activities, or to reallocate resources. Modularity was theoretically shown to aid in a lean process and to create buildability by promoting a high productivity. The modular approach enables easier management of the lean main practices by just-in time deliveries, scheduling, quality, and flexibility etc. Buildability is, by the modular approach, promoted already during design by enabling accurate fit between elements within a module and between the modules themselves (Björnfot and Stehn, 2004). Buildability during production is further enabled by the simplified organization of materials and resources.

Due to the adverse participant relations and the segregated construction process, the Swedish timber construction industry is, at this date, not mature enough to handle the implementation of lean practices as is. The focus for timber construction should therefore instead be product modularity, i.e., a bottom-up product focused view. Such a view has potential to be a driving force in the struggle for industrialization of construction.

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Industrialization of Construction – a Lean Modular Approach

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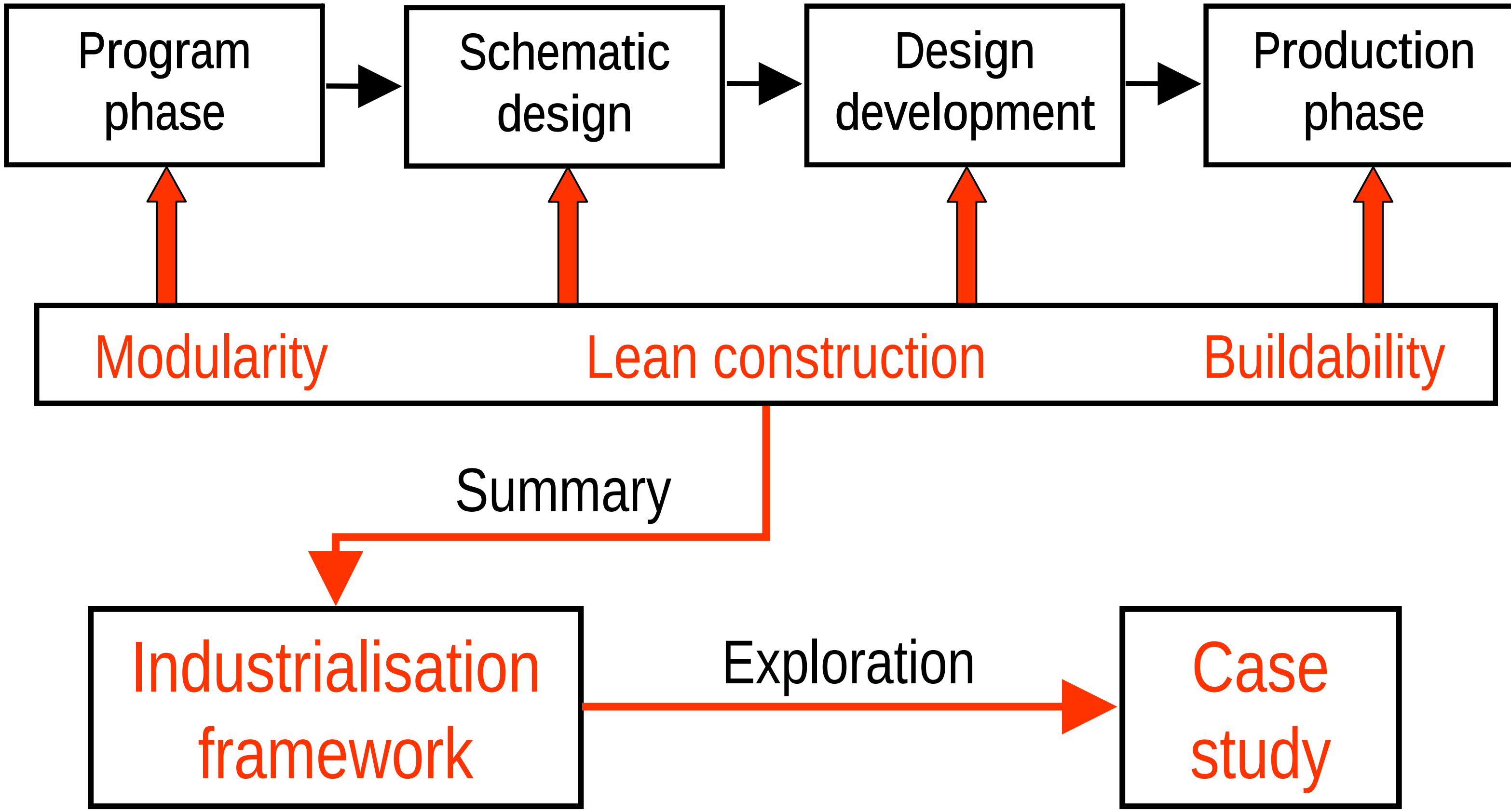
Research method

The conventional D&B construction process is used as base of discussions



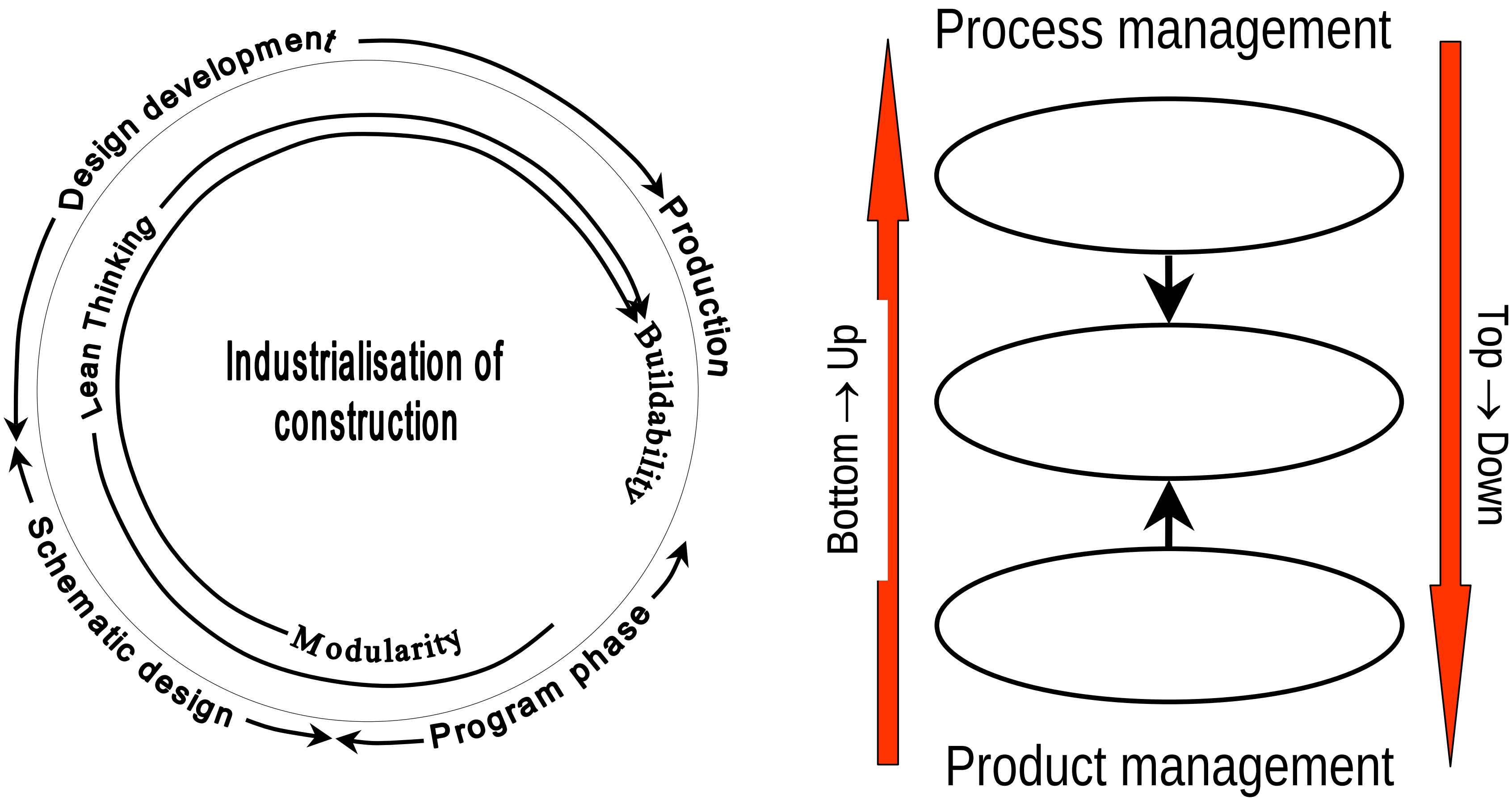
Industrialisation principles

- Modularity is both a process and product discipline offering a wide variety of advantages in the whole construction process. Modularity is applied at the product level and realised in design development and production.

- Lean construction is a process management discipline offering management in the whole construction process, aimed at streamlined production.

- Buildability is a process and product based discipline. In contrary to modularity; buildability is more of a goal than a means for product and process efficiency.

Summary - Industrialisation framework



Framework → Application?

Case study – assembly process

Sequential assembly process

- 4 weeks until finished structural assembly
- General assembly activities; sub-assembly, placement, and final assembly
- Resources used; up to a 3 men workforce, 2 tower-cranes, and 2 sky-lifts

Modularity simulations

What is the usefulness of thinking in modularity during assembly?

"Thinking" modularity offers;

- Increased self-control
- Improved quality
- Opportunity for out-sourcing
- Guidance for pre-assembly
- Guidance for prefabrication
- Reallocation of resources

} Product buildability
Process buildability
Lean thinking

Discussion and conclusions

- Modularity has been one of the driving forces in the evolution of the manufacturing industry
- In construction, the product is usually not unique, the setting is!
- Modularity confers both product and process buildability
- Modularity aids in the implementation of lean thinking in construction
- The Swedish construction industry is not mature enough to handle the direct implementation of lean practices as is…
- …the construction industry should initially focus on product modularity – a "bottom-up" product focused view…

THE LAST PLANNER SYSTEM OF PRODUCTION CONTROL

by

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ABSTRACT

Project controls have traditionally been focused on after-the-fact detection of variances. This thesis proposes a control system, the Last Planner system, that causes the realization of plans, and thus supplements project management's concern for management of contracts with the management of production.

The Last Planner system has previously been successively applied by firms with direct responsibility for production management; e.g., speciality contractors. This thesis extends system application to those coordinating specialists, both in design and construction, through a series of case studies, one of which also explores the limits on unilateral implementation by specialists.

In addition to the extended application, two questions drive this research. The first question is 1) *What can be done by way of tools provided and improved implementation of the Last Planner system of production control to increase plan reliability above the 70% PPC level?* Previous research revealed substantial improvement in productivity for those who improved plan reliability to the 70% level, consequently there is reason to hope for further improvement, possibly in all performance dimensions, especially with application across an entire project rather than limited to individual speciality firms. That question is explored in three case studies, the last of which achieves the 90% target.

The second research question is *2) How/Can Last Planner be successfully applied to increase plan reliability during design processes*[1]*?* That question is explored in an extensive case study, which significantly contributes to understanding the design process from the perspective of active control, but unfortunately does not fully answer the question, primarily because the project was aborted prior to start of construction. However, it is argued that the Last Planner system is especially appropriate for design production control because of the value-generating nature of design, which renders ineffective traditional techniques such as detailed front end planning and control through after-the-fact detection of variances.

[1] In this thesis, the term "design" is used to designate both design and engineering activities, not shaping space to aesthetic criteria.

Issues for future research are proposed, including root cause analysis of plan failures and quantification of the benefits of increased plan reliability for both design and construction processes.

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CHAPTER ONE: INTRODUCTION

1.0 Conceptual Framework

Production processes can be conceived in at least three different ways: 1) as a process of converting inputs to outputs, 2) as a flow of materials and information through time and space, and 3) as a process for generating value for customers. All three conceptions are appropriate and necessary. However, the conversion model has been dominant in the AEC (architectural/engineering/construction) industry until very recently (Koskela and Huovila, 1997).

Table 1.1

	Conversion View	Flow View	Value Generation
Nature of Construction	**a series of activities which convert inputs to outputs.**	**the flows of information & resources, which release work: composed of conversion, inspection, moving and waiting.**	**a value creating process which defines and meets customer requirements.**
Main Principles	**Hierarchical decomposition of activities; control and optimization by activity.**	**Decomposition at joints. Elimination of waste (unnecessary activities), time reduction.**	**Elimination of value loss - the gap between achieved and possible value.**
Methods & Practices	**Work breakdown structure, critical path method. Planning concerned with timing start and responsibility for activities through contracting or assigning.**	**Team approach, rapid reduction of uncertainty, shielding, balancing, decoupling. Planning concerned with timing, quality and release of work.**	**Development and testing of ends against means to determine requirements. Planning concerned with work structure, process and participation.**
Practical Contribution	**Taking care to do necessary things.**	**Taking care that the unnecessary is done as little as possible.**	**Taking care that customer requirements are met in the best possible manner.**

Conversion/Flow/Value[2]

The design and construction of AEC facilities (buildings, process plants, airport terminals, highways, etc.) poses difficult management problems to which the models and techniques based on the conversion view have proven inadequate. Tradeoffs between competing design criteria must be made throughout the design process, often with incomplete information and under intense budget and schedule pressure. Increasingly, projects are subject to uncertainty because of the pace of technological change and the rapid shifting of market opportunities and competitor actions.

Production management concepts and techniques based on the conversion model have not proven capable of solving these difficult problems. The heart of the conversion model is the assumption that the work to be done can be divided into parts and managed as if those parts were independent one from another. Management techniques such as work breakdown structures and earned value analysis belong to this conversion model. Work breakdown structures are driven by scoping and budget concerns and have the objectives of insuring that all the work scope is included in one of the parts, insuring that no work scopes overlap, and allocating costs to each part such that the rollup yields the total for the project. This division into parts is necessary in order to allocate responsibility to internal or external work centers, which can subsequently be controlled against scope, budget, and schedule commitments.

This is fundamentally a contracting mentality, which facilitates the management of contracts rather than the management of production or work flow. Production management is the 'local' responsibility of those to whom the various parts are assigned or contracted. If everyone meets their contractual obligations, the project performs successfully. Unfortunately, this approach is the opposite of robust. When something goes wrong, as it very often does, the entire structure is prone to collapse.

If a management philosophy and tools are needed that fully integrate the conversion, flow, and value models, we might consider the product development processes employed by firms designing and manufacturing consumer products (automobiles, printers, toasters, etc.). Such processes have developed potentially useful concepts especially in the area of value; identification of customer needs and translation into engineering specifications (Ulrich and Eppinger 1993). Product development processes also are struggling with other issues relevant to the design of AEC facilities, including design decomposition, organizational means for integration, etc. (Hayes, et al, 1988; Eppinger, et al, 1990; Gebala and Eppinger, 1991).

As a contribution to the integration of all three models, this thesis applies the flow model to managing the design and construction of AEC facilities. Conceptualizing the design and construction process as a flow of information and materials lends itself to reducing waste by minimizing time information or materials spend waiting to be used, time spent inspecting information or materials for conformance to requirements, time spent reworking information or materials to achieve conformance, and time spent moving information or materials from one specialist to the next. Further, conceptualizing the design and construction process as a flow of information and materials allows coordination of interdependent flows and the integration of design with supply and site construction.

1.2 Assumptions

Fundamental assumptions underlying this research include the following:

- Current construction industry production management thinking and practice is dominated by the conversion model, consequently value generation and flow management concepts and techniques are underdeveloped.
- To be consistent with all three models, conversion, flow, and value, production management should be conceived as having the purpose of creating customer value while minimizing waste in time and cost. “Customer value” is understood to include not only the fitness for use of the facility considered with regard to functionality, but also with regard to all other criteria to which the customer attaches value, e.g., project delivery within a time and for a cost that meets the customer’s market and financial needs.
- "Production" is understood to include both designing and making. The historical development of production theory in manufacturing has erroneously suggested that production is entirely concerned with 'making'.[3]
- Production management is conceived to consist of criteria determination and work structuring in the ‘planning’ phase, and to consist of work flow control and production unit control in the ‘execution’ or ‘control’ phase.

This thesis treats only control functions, not planning functions. It does not treat the very first and fundamental production management activity; i.e., the determination of customer needs and their translation into design criteria. Criteria determination belongs to the value generation view. This thesis treats only the flow view. Similarly, work structuring activities such as identification, sequencing, and scheduling tasks are also not

[3] There may be differences between the U.S. and U.K. in the use of these terms. Hence the effort to be precise. For the most part, the theory of producing artifacts has emerged from efforts to better manage factories. More recently, in some instances, the term "manufacturing" has acquired greater scope than merely factory production.

treated here. The scope of this thesis is the control functions of production unit control and work flow control.

1.3 Contribution to Knowledge

This dissertation proposes to make the following contributions to knowledge:

- Adapted from manufacturing[4], a system for production control, the Last Planner system, is presented that exemplifies the concept of control as causing events to conform to plan, as distinct from the traditional conception of project control in terms of after-the-fact variance detection.
- Appropriate application of the production control system is shown to improve work flow reliability, which promises substantial benefits in project cost and duration reduction.
- Improvements to the Last Planner system of production control are developed and tested in a series of case studies, resulting in new concepts and techniques.

Project controls in the AEC industry have focused on detecting variances from project objectives for cost and schedule, and have not directly dealt with the management of production. The Last Planner system of production control has proven an effective tool for improving the productivity of the production units that implement its procedures and techniques (Ballard and Howell, 1997). This dissertation shifts the focus from the productivity of the immediate production unit to the reliability of work flow between production units, and also extends application of the system to design.

1.4 The Author's Role in the Research

[4] I.e., from the models and theories developed in industrial engineering

The Last Planner system has been in development by the author since 1992. Several papers have previously been published by this author on the subject, the first of them in 1993 (Ballard, 1993) at the founding conference of the International Group for Lean Construction. Last Planner research began with a focus on improving the quality of assignments in weekly work plans (Koch Refinery Mid-Plants Project, 1993-4[5]), added a lookahead process to shape and control work flow (PARC, 1995[6]; DMOS-6, 1996[7]), and eventually was extended from construction to design (Nokia[8] and Hewlett-Packard[9], 1996). During that development, the objective shifted from improving productivity to improving the reliability of work flow. This resulted from a change in conceptual framework. The initial framework came from the quality management and productivity improvement initiatives that dominated construction industry performance improvement efforts in the 1980s. The shift to work flow reliability reflected the author's increasing awareness of the revolution in manufacturing inspired by the Toyota Production System and eventually labeled "lean production", and also contact with the thinking of Lauri Koskela regarding production theory and its application to the construction industry.

A key metric of the Last Planner system is the percentage of assignments completed (PPC), which is clearly a defect rate and a product of the quality management mentality. Given the objective of improving productivity, measurements were made of the relationship between the defect rate of a crew, its PPC, and the productivity of that crew. Not surprisingly, such measurements revealed a positive correlation[10]. However, the

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[5] Ballard and Howell, 1997
[6] Ballard, Howell, and Casten (1996)
[7] Ballard and Howell, 1997
[8] Koskela, Ballard, and Tanhuanpaa (1997)
[9] Miles (1998)
[10] For examples, see the references footnoted previously.

activity focus characteristic of the productivity improvement 'mind' concealed the importance of that crew's PPC for the productivity of the crews that followed it and built upon its work product. Even the introduction of a lookahead process was motivated initially by the observation that simply shielding a crew from poor assignments was insufficient to optimize crew productivity. To do so required matching load and capacity, both of which required managing load or work flow. The more powerful and fundamental opportunity to coordinate action among multiple crews was hidden by the dominance of what Koskela has called the "conversion model" and its exclusive focus on the activity as the unit of control rather than work flow.

Prior to the founding of the Lean Construction Institute (LCI) in August of 1997[11], the Last Planner system had evolved to roughly its current form, with a clear conceptual basis in production theory a la Koskela and an explicit and self-conscious objective of managing work flow. What remained to be done was to learn how to improve work flow reliability above the 35%-65% range commonly discovered up to that time. One purpose of this dissertation is to describe what was done to improve work flow reliability, measured by PPC, and the results achieved. That improving work flow reliability is beneficial hardly requires argument. However, identifying and quantifying the specific benefits will be a matter for future research. The second purpose of this research is to explore applicability of the Last Planner system to design.

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[11] The Lean Construction Institute was founded in August of 1997 as a partnership between Gregory A. Howell and Glenn Ballard, dedicated to research, training and consulting in construction industry production management. Subsequently, Iris Tommelein and Todd Zabelle have become partners in the enterprise, along with Mark Reynolds, Managing Director of Lean Construction International, based in London. All the case studies reported in this thesis were undertaken as research projects for LCI, of which this author is Research Director. All case studies were carried out under the

1.4 Structure of the Dissertation

Traditional project control theory and practice is described and critiqued in Chapter Two. The Last Planner System of Production Control is presented in Chapter Three as satisfying the requirements revealed by the critique. Chapter Four describes the research methodology used in the dissertation and is followed by Chapters 5, 6, 7, 8, and 9, each devoted to a case study. Conclusions from the case studies are reported in Chapter 10, followed by a glossary of terms, a list of references, a bibliography, and an appendix consisting of documents from the design case, Next Stage.

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direction of this author, who also was the primary participant in project events and the primary collector of case study data.

CHAPTER TWO: CRITIQUE OF PRODUCTION CONTROL

2.1 What is Production Control?

The purpose of this chapter is to provide a critique of production control theory and practice. But first it is necessary to clarify what is meant by “production control”.

2.1.1 The Meaning of “Production”

Production has been an explicit topic of study primarily in industrial engineering, which has dealt almost entirely with one type of production; namely, manufacturing (in the sense of 'making'), with only occasional forays into construction, plant maintenance, building maintenance, agriculture, forestry, mining, fishing, etc. Design and engineering have infrequently been conceived as production processes; the focus almost entirely being placed on making things rather than designing them.

Although the meaning of the term at its most universal is synonymous with “making”, “manufacturing” is most commonly[12] used to denote the making of many copies from a single design, and consequently is primarily focused on products for a mass market, most of those products being moveable from the place manufactured to the place of use. There are exceptions to the products being moveable, although still copies from a single design; e.g., ships and airplanes. Within the world of construction, manufacturing in this sense is approached mostly closely by 'manufactured housing'.

[12] Exceptions occur with thinkers and writings regarding product development, which by its nature must integrate designing and making, at least in the sense of making prototypes.

Various types of making have been proposed, among them ‘assembly’, the joining of parts into a whole, as distinct from ‘fabricating’, the shaping of materials. For example, construction is often categorized as a type of ‘fixed position manufacturing’ (Schmenner, 1993), along with shipbuilding and airplane assembly. In all these instances of assembly, the assembled product eventually becomes too large to be moved through assembly stations, so the stations (work crews) must be moved through them, adding additional components and subassemblies until the artifact (building, bridge, tunnel, plant, house, highway, etc) is completed.

Many publications exist on the topic of production management in manufacturing, the larger part of which adopt the perspective of the industrial or production engineer (Bertrand et al, 1990; Hopp and Spearman, 1996; Murrill, 1991; Vollman et al, 1992). A subset of this category concern themselves with the psychological/sociological aspects of manufacturing management (Scherer, 1998). The development of alternatives to mass production over the last 40 years has been revolutionary. Early and influential production management theorists include Jack Burbidge (1983; 1988) and W. Edwards Deming (1986), to mention but a few from the West. Taiichi Ohno (1988) and Shigeo Shingo (1988) were the primary architects of the Toyota Production System, the archetype for lean production, so named in part to counterpose it to "mass" production. Burbidge's groundbreaking thought began to emerge in the 1960s. Deming was instrumental in the implementation of quality management and statistical quality control concepts and techniques in Japan after the 2nd World War. The work of Ohno and Shingo was concentrated in the period of the late 50's into the 70's. *The Machine That Changed the World* (Womack et al., 1990) reported the findings of an international study of the automotive industry and was followed by *Lean Thinking* (Womack and Jones, 1996) which presented the principles and basic concepts behind the new forms of manufacturing and proposed to extend them to the entire enterprise. Womack and Jones have popularized and made more easily accessible the concepts and techniques of lean production.

Defining production as the designing and making of artifacts allows us to understand how construction is a type of production and also that design is an essential component in production generally and in construction specifically. Lauri Koskela (Koskela 1992, 1999; Koskela and Huovila 1997; Koskela et al. 1996, 1997) is the foremost production theorist in construction. His study of the applicability of newly emergent manufacturing concepts and techniques to the construction industry has driven him back to the development of a theory of production as such (Koskela, 1999).

2.1.2 THE MEANING OF "CONTROL"

The term "control" has a wide range of meanings. According to the Concise Oxford Dictionary, its meanings include to dominate, command; to check, verify; to regulate. It has long been associated with accounting. The Old French *contreroller*: to keep a roll of accounts.

Accounting is the essence of project control theory, more fully described in section 2.2.2 below (Diekmann and Thrush, 1986; Project Management Body of Knowledge (PMBOK), 1996; Riggs, 1986). The essential activity is monitoring actual costs or schedule performance against target in order to identify negative variances. Corrective action is obviously necessary in order to correct such negative variances, but the literature hardly addresses corrective action.

Industrial process control introduces feedback and feedforward mechanisms for regulating a process (Murrill, 1993). Feedback is initiated by a comparison of actual with target outputs. Feedforward is initiated by a comparison of actual with target inputs.

The artificial intelligence community contributes the blackboard system of control, in which coordination of a number of interdependent specialists is managed by rules for taking turns 'writing on a blackboard'; i.e., for contributing to their collaborative work (Hayes-Roth, 1985). AI adherents have been in the forefront of empirical study of design, and despite their technological orientation, have found social and organizational issues to be of great importance. Finger et al (1995) conclude: “The social process plays a major role in the articulation and realization of the product design, particularly in large projects.” (p.89). Bucciarelli (1984) reports that designers spend 85-90% of their time talking, writing, negotiating, meeting, searching, etc. as opposed to drawing and calculating.

Production control theorists working in manufacturing distinguish two primary ways of regulating work flow in manufacturing systems: push and pull. Push systems release materials or information into a system based on preassigned due dates (from a master production schedule, for example) for the products of which they are parts. Pull systems release materials or information into a system based on the state of the system (the amount of work in process, the quality of available assignments, etc) in addition to due dates (Hopp and Spearman, 1996). In factory systems, pull may be derivative ultimately from customer orders. In construction, pull is ultimately derivative from target completion dates, but specifically applies to the internal customer of each process. Applicability of these concepts to production control has been explored by this author (Ballard, 1999).

Some theorists (Kelly, 1994) propose that complex, dynamic systems are regulated not by anything resembling a central mind, but through the independent action of distributed decision makers. The following excerpt from Eric Scherer's introduction to *Shop Floor Control-A Systems Perspective* indicates the emergence of a new conceptual framework,

> *"To master the challenges of the future, there must be a change in our thinking paradigm. Manufacturing is not deterministic! …the problem of systems design for shop floor control is no longer the problem of 'optimization'. The reductionistic paradigm … needs to be replaced by a holistic paradigm of agile activity, dynamic behavior, and evolutionary development."*

2.2 Project Management

2.2.1 THE PROJECT MANAGEMENT BODY OF KNOWLEDGE

The construction industry is organized in projects and current production theory and practice are heavily influenced by the concepts and techniques of project management. According to PMI's *A Guide to the Project Management Body of Knowledge*, "a project is a temporary endeavor undertaken to produce a unique product or service." The making (i.e., manufacturing) of multiple copies of a product does not occur through projects so understood. This focus on product uniqueness and the project form of organization has dominated thinking about production of the built environment so far as to discourage learning from non-project industries such as product manufacturing (Koskela, 1992).

Again according to PMI (1996), project management includes the management of integration, scope, time, cost, quality, human resources, communications, risk, and procurement. Any or all of these could conceivably concern the actual production process itself, but perhaps most of all time and cost.

Time management is said to consist of activity definition, activity sequencing, activity duration estimating, schedule development, and schedule control. The focus is entirely on delivering project objectives; in Koskela's terms, on the transformation or conversion processes (activities) and not on flow or value generation processes. Activities are to be defined so as to facilitate a division of labor and subsequent tracking (accounting) of conformance to requirements. There is no mention of structuring work for flow or of defining activities so that they facilitate the actual performance of the work. Activity sequencing assumes that handoffs from one set of specialists to the next occur only once; that there is no repetition or cycling to be managed ("conditional diagramming methods" are mentioned-see page 63-but not developed). Schedule control is concerned with managing changes to the schedule rather than with execution of scheduled work; with the exception of expediting as a type of time management corrective action (see page 72). Cost management is treated very much in the same way as time management. The question for project management thus remains: 'Who manages production and how?'

PMI differentiates between project processes and product-oriented processes (page 27), the former being characteristic of all types of projects and the latter specific to the various types of production with which projects may be involved. What is missing in this distinction is the concept of the project itself as a temporary production system linked to other temporary and permanent production systems for materials, equipment, labor, etc. Projects as such have no necessary connection with production. For example, a project may be to solve a problem of getting voters to register. In this broad sense of the term, 'project' becomes virtually synonymous with a single instantiation of the problem solving process, and project management consists of the tools and techniques for managing problem solving processes in groups. On projects that do have production objectives, production itself takes place alongside project management, but is not directly the business of project management. Consequently, project control consists of monitoring progress toward project objectives and taking corrective action when the ship appears to be off course.

This concept of project control is very different from production control, which is dedicated to causing events to conform to plan and to replanning when events cannot be conformed. Production control conceives production as a flow of materials and information among cooperating specialists, dedicated to the generation of value for customer and stakeholders.

2.2.2 Critique of the Traditional Project Control Model

Project control has been hitherto conceived and carried out consistently with the conversion or transformation view of projects (Koskela and Huovila, 1997). The received wisdom regarding AEC project control systems is founded on a widely shared conception of their purpose. "This (project control) system must provide the information needed for the project team and project participants to identify and correct problem areas and, ultimately, to keep project costs and schedule 'under control'." (Diekmann and Thrush, 1986). The objective is to detect negative variances from target, so corrective action can be taken. This is quite different from the active concept of control dominant in manufacturing production control systems, especially those employing a pull strategy, in which the purpose of control is to cause events to conform to plan. In the following, we further examine traditional project controls and their difference from the concept of control in the Last Planner system, which is to be introduced in Chapter 3.

In traditional project control, the objects of control are time and resources. Resources (labor hours, material, equipment, indirects) are planned and controlled through cost control systems, the objective of which is productivity, i.e., efficient use of resources. A budget is prepared for each resource, the use of resources is monitored against their budgets, and periodic forecasts are made of resource requirements based on the current state of the project.

Controlling time involves planning, scheduling, and monitoring. Planning decides what is to be accomplished and in what sequence. Scheduling determines task duration and timing. Monitoring checks progress of tasks against the schedule and forecasts when work will be completed. The objective of time control is production or progress, not productivity.

Decisions made regarding budget and schedule, productivity and production must recognize their interdependence. Productivity and production are formally related in earned value systems, which propose a solution to the problem that progress and expenditure of resources need not coincide. Rates of resource consumption are established for the various kinds of work to be performed on a project; e.g., 9.32 engineering labour-hours per piping isometric drawing or 12.4 labour-hours per purchase order. Completing an individual piping isometric drawing earns 9.32 labour-hours regardless of the actual number of hours consumed in its production. Progress toward project completion is tracked by accumulating the earned hours and comparing that to the total hours to be earned for the entire project. For example, suppose the project schedule calls for production of 10 piping isometric drawings at time t, but only 9 drawings have been produced. Only 83.88 (9 x 9.32) hours have been earned of the 93.2 scheduled, so that portion of the project is 10% behind schedule (83.88/93.2=.90). That is a measure of production against schedule.

Productivity can be quite a different story. Suppose it has taken only 80 hours to produce the 9 piping isometric drawings. Since 83.88 hours were earned, the performance factor is .95 and the piping group is operating at 95% of its budget for isometric drawings. In this case, the project is behind schedule, but under budget. Production is poor and productivity is good.

Earned value analysis is a means for controlling projects through productivity and progress. By itself, it would have the design manager believe that a project is performing well if it is earning labor hours at the budget unit rate and also earning sufficient hours to maintain a scheduled earnings plan expressed as percentages of earned hours to total hours to be earned. The obvious weakness in this control mechanism is that projects may exhibit budget productivity and be on the earnings plan, but not be doing the right work in the right way at the right time. Although things appear to be on track, the train is destined to eventually run off the rails because work is being produced that does not conform to product quality requirements or to process quality requirements (e.g., out of sequence). Consequently, quality control is invoked as a separate control mechanism, although rarely if ever controlling against the objective of expressing customer needs in engineering specifications, but rather controlling against the objectives of avoiding calculational and dimensional errors. As for the issue of the timing of work, it has proven necessary to establish schedule milestones to enforce adherence to a work sequence. These rear guard actions are frequently ineffective against the dominant progress and productivity controls, which consequently cause managers to throw the lever in the wrong direction because they misevaluate actual project performance (Howell and Ballard, 1996).

Work Breakdown Structure (WBS) is a key element in traditional project controls. “A WBS provides a framework for integrated schedule and cost planning and allows for monitoring and control by management by establishing the manner in which estimates are assigned and costs are accumulated and summarized.” (p. 21, Diekmann and Thrush, 1986). The objective is to divide the work to be done in the project into parts so they can be monitored and controlled. No mention is made of the production process as such. [NB: Inclusion of the flow view adds new criteria to the decomposition process. Roughly speaking, we want to break the whole into parts so we can more easily put the parts back together again. Structure work for flow and assembly, not only for budgeting and monitoring.]

Further decomposition in the traditional process eventually defines work packages as the smallest unit. Work packages often correspond to contract packages or to pay items within a single contract. The dominance of the conversion view is perhaps best revealed in the following quotes: “A work package is a cost center.” (p. 73, Neil, James M. *Construction Cost Estimating for Project Control*, 1982). “The WBS provides the framework for defining the project from the top all the way down to its smallest components and for accumulating the costs associated with each piece. In so doing, the WBS provides a data base from which problem areas can be identified, forecasts made, and corrective action can be taken.” (p. 21, Diekmann and Thrush, 1986). It appears to be assumed that costs arise within that part of the project in which they are detected. Further, control is essentially control of behaviour, given the default assumption that tasks/work packages/contracts can be carried out. The flow view, with its interdependence of parts (both as regards the 'product' and the process of making that product), is neglected in this perspective. Equally neglected is consideration of capability.

We are clearly dealing here with a type of push system and the controls appropriate to a push system.

Despite the focus on cost and schedule ‘accounting’, theorists recognize the primacy of the control act itself. “Without corrective actions a project control system becomes merely a cost/schedule reporting system.” (p. 29, Diekmann and Thrush, 1986). However, the traditional view is that control consists of correcting deviations from plan. Deviations are expected, but that expectation is not rooted in the idea that variation is natural, but rather that sin is inevitable. Diekmann and Thrush devote less than two pages of a 108 page paper to corrective action and provide no more advice than to inform managers and supervisors at every level in the project about deviations so they can “…correct those trouble spots.” (p. 28). They appear to assume that causes of deviation will be apparent and the appropriate corrective action obvious. “These problems can be easily traced to their source allowing early detection of unfavorable trends.” (p. 33, Diekmann and Thrush, 1986). If the standard corrective actions are indeed ‘Try harder!’ and ‘Add more men!’, that would be consistent with the traditional view.

Advocates of system dynamics have proposed to supplement traditional network analyses and models, adding to the “…growing evidence that network analysis on its own is not sufficient to model and manage the behaviour of projects.” (Williams et al., 1995, p. 154). They propose to provide additional information to project managers so they avoid misevaluating the state of the project and consequently making decisions that cause things to get worse rather than better (See p. 125 of Rodrigues, 1994). Ballard and Howell (1996) suggest that it is impossible to make good decisions about causes or corrections of deviations, relying only on productivity and progress data, without understanding work flow. One can hardly avoid concluding that the traditional control system is indeed based almost exclusively on the conversion or activity view of the production system.

2.3 Previous Applications of Production Control Concepts to the AEC Industry

A survey of the literature reveals several primary contributors to the theory and practice of production (as opposed to project) control in the construction industry. Ballard and Howell's contributions are described in Chapter Three. Melles and Wamelink (1993) developed a very similar line of thinking independently, culminating in their joint PhD thesis at Delft University, The Netherlands. Lauri Koskela, Senior Researcher at Finland's building research institute, VTT, is the leading theorist in production management in construction. The University of Reading has been active in the field of production management for a number of years. John Bennett's *Construction Management* from 1985 is an excellent example of their work. Addis' 1990 book, *Structural engineering: the nature and theory of design*, is also a highly relevant work for this research. Alexander Laufer's work on project planning takes a production control orientation by virtue of its focus on uncertainty and variability and their management. Given the relative obscurity of Melles and Wamelink's, only their work is presented in detail. The work of Koskela is described only to the extent needed to remind the reader of his vital contributions. That should in no way be taken as an indication of relative importance of the various contributions.

2.3.1 MELLES AND WAMELINK

Introducing their discussion of the theory of production control, Melles and Wamelink (1993) explain, "Contrary to what is customary in the construction industry we shall not assume, beforehand, the theories in the field of project management. …Production control in construction companies has traditionally been aimed at the control of projects." For Melles and Wamelink, production control consists of "…the activities relating to the adjustment of all aspects of the production process, so that the preconditions in which the production process is to be executed, are met." Drawing on manufacturing production control, they emphasize: 1) Thinking in terms of hierarchical levels of decision; i.e., control at company level, factory level, and production unit level, and 2) Thinking in terms of decision functions within the hierarchical levels; i.e., aggregate production control, material coordination, workload control, workorder release, workload acceptance, detailed workorder scheduling, capacity allocation, and shop floor control. The manufacturing model on which they rely is that of Bertrand et al., 1990.

Melles and Wamelink propose a 'translation' of the manufacturing model into decision functions appropriate to various types of construction, identifying at the 'factory' level project coordination (achieved in part by network schedules), mobilisation planning (by means of "six weeks scheme"), and allocation planning (by means of "task scheme").

In addition to the primary contribution of directing attention to manufacturing theory and practice, Melles and Wamelink's work identifies functionalities AEC industry production control systems should possess. Their specific objective was to assist in the design of information systems. Consequently, they did not explicitly apply their model to evaluation of current management systems and practice. However, the overwhelmingly negative results of so doing are implicit in their critique of project management software. For example, speaking of project coordination, they comment, "…it can immediately be deduced that the project management software available on the market is indeed about a certain aspect (within the framework, the decision function project coordination). The other decision functions (resource planning, mobilization planning, etc.) are, generally speaking, not recognizable." (p. 35). This critique is made more explicitly in Wamelink et al., 1993.

2.3.2 KOSKELA

Lauri Koskela (1999) proposes the following design criteria or principles for a production control system. In fact, he claims they are true for the Last Planner system, which is to be presented in Chapter Three:

> "The first principle is that the assignments should be sound regarding their prerequisites. This principle has also been called the Complete Kit by Ronen (Ronen 1992). The Complete Kit suggests that work should not start until all the items required for completion of a job are available. Thus, this principle strives to minimize work in suboptimal conditions.
>
> "The second principle is that the realization of assignments is measured and monitored. The related metrics, Percent Plan Complete (PPC), is the number of planned activities completed, divided by the total number of planned activities, and expressed as a percentage. This focus on plan realization diminishes the risk of variability propagation to downstream flows and tasks.
>
> "Thirdly, causes for non-realization are investigated and those causes are removed. Thus, in fact, continuous, in-process improvement is realized.
>
> "The fourth principle suggests maintaining a buffer of tasks which are sound for each crew. Thus, if the assigned task turns out to be impossible to carry out, the crew can switch to another task. This principle is instrumental in avoiding lost

production (due to starving) or reduced productivity (due to suboptimal conditions).

"The fifth priciple suggests that in lookahead planning (with time horizon of 3-4 weeks), the prerequisites of upcoming assignments are actively made ready. This, in fact, is a pull system that is instrumental in ensuring that all the prerequisites are available for the assignments. On the other hand, it ensures that too great material buffers do not emerge on site."

2.4 Criteria for a Design Production Control System

The preceding review and critique of the literature suggests the following guidelines and criteria for an effective design production control system:

- *Variability must be mitigated and remaining variability managed.* Variability is virtually disregarded in current control systems. But the construction industry certainly has its share of variability: variability in quality, variability in processing times, variability in deliveries, etc. Neglect of variability causes greater variability, and there is always an associated penalty. According to Hopp and Spearman (1996), variability results in some or all of the following:
    - buffering of flows, which increases lead times and work-in-process
    - lower resource utilization
    - lost throughput
- *Assignments are sound regarding their prerequisites.*
- *The realization of assignments is measured and monitored.*
- *Causes for failing to complete planned work are investigated and those causes are removed.*
- *A buffer of sound assignments is maintained for each crew or production unit.*
- *The prerequisites of upcoming assignments are actively made ready.*
- *The traditional schedule-push system is supplemented with pull techniques.* Not only do pull systems usually perform better than push systems (Hopp and Spearman, 1996), but pull systems are

especially needed in conditions of variability.

- *Production control facilitates work flow and value generation.* Production thinking and practice in all areas has focused primarily on the task goals of production and neglected flow and value (Huovila and Koskela, 1997). The object of traditional project control has been behavior. What needs to be controlled is work flow.
- *The project is conceived as a temporary production system.* The model for corrective action in traditional project control is course correction, drawn by analogy from the path of a vehicle bound for a specific destination with a target arrival time and a specified spending budget or otherwise limited resources. If the project is to be conceived rather as a temporary production system, the course correction model is radically oversimplified and inappropriate. The flow of materials and information is what is to be controlled. They flow through very complex networks of temporary and permanent production systems. Corrective action must be taken within an understanding of these networks and of the impact of changes in sequence, processing methodologies, buffer location and sizing, local control strategies (e.g., pull or push), etc.
- *Decision making is distributed in production control systems.* Traditional project control assumes the necessity and possibility of central control. The underlying image is that of a single mind and many hands. Arguably, dynamic production systems cannot be controlled centrally, but rather are adaptive creatures driven by decision making at their periphery.
- *Production control resists the tendency [of designers and engineers] toward local suboptimization* (Green, 1992). Green's comment was specifically directed to the tendency of designers and engineers toward local suboptimization, but that is a general tendency of any system in which there is a division of labor.

In Chapter Three, the Last Planner system of production control is described and evaluated against these criteria.

CHAPTER THREE: DESCRIPTION AND HISTORY OF THE LAST PLANNER SYSTEM OF PRODUCTION CONTROL

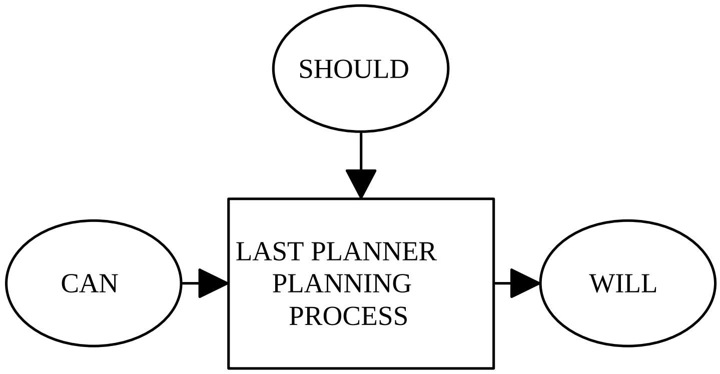
3.1 Hierarchical Structure

Aside from the simplest and smallest jobs, design and construction require planning and control done by different people, at different places within the organization, and at different times during the life of a project. Planning high in the organization tends to focus on global objectives and constraints, governing the entire project. These objectives drive lower level planning processes that specify means for achieving those ends. Ultimately, someone (individual or group) decides what physical, specific work will be done tomorrow. That type of plans has been called "assignments". They are unique because they drive direct work rather than the production of other plans. The person or group that produces assignments is called the "Last Planner" (Ballard and Howell 1994).

3.2 Should-Can-Will-Did

The term "assignments" stresses the communication of requirements from Last Planner to design squad or construction crew. But these products of planning at the production unit level are also commitments to the rest of the organization. They say what WILL be done, and (hopefully) are the result of a planning process that best matches WILL with SHOULD within the constraints of CAN.

Figure 3.1



The formation of assignments in the Last Planner planning process.

Unfortunately, last planner performance is sometimes evaluated as if there could be no possible difference between SHOULD and CAN. "What will we do next week?" "Whatever is on the schedule," or "Whatever is generating the most heat." Supervisors consider it their job to keep pressure on subordinates to produce despite obstacles. Granted that it is necessary to overcome obstacles, that does not excuse creating them or leaving them in place. Erratic delivery of resources such as input information and unpredictable completion of prerequisite work invalidates the presumed equation of WILL with SHOULD, and quickly results in the abandonment of planning that directs actual production.

Failure to proactively control at the production unit level increases uncertainty and deprives workers of planning as a tool for shaping the future. What is needed is to shift the focus of control from the workers to the flow of work that links them together. The Last Planner production control system is a philosophy, rules and procedures, and a set of tools that facilitiate the implementation of those procedures. Regarding the procedures, the system has two components: production unit control and work flow control. The job of the first is to make progressively better assignments to direct workers through continuous learning and corrective action. The function of work flow control is perhaps evident in its name—to proactively cause work to flow across production units in the best achieveable sequence and rate.

3.3 Production Unit Control

The key performance dimension of a planning system at the production unit level is its output quality; i.e. the quality of plans produced by the Last Planner. The following are some of the critical quality characteristics of an assignment:

- The assignment is well defined.
- The right sequence of work is selected.
- The right amount of work is selected.
- The work selected is practical or sound; i.e., can be done.

“Well defined” means described sufficiently that it can be made ready and completion can be unambiguously determined. The "right sequence" is that sequence consistent with the internal logic of the work itself, project commitments and goals, and execution strategies. The "right amount" is that amount the planners judge their production units capable of completing after review of budget unit rates and after examining the specific work to be done. "Practical" means that all prerequisite work is in place and all resources are available.

The quality of a front line supervisor's assignments may be reviewed by a superior prior to issue, but such in-process inspection does not routinely produce measurement data, even when corrections are necessary. Planning system performance is more easily measured indirectly, through the results of plan execution.

Percent Plan Complete (PPC) is the number of planned activities completed divided by the total number of planned activities, expressed as a percentage. PPC becomes the standard against which control is exercised at the production unit level, being derivative from an extremely complex set of directives: project schedules, execution strategies, budget unit rates, etc. Given quality plans, higher PPC corresponds to doing more of the right work with given resources, i.e. to higher productivity and progress.

Percent Plan Complete measures the extent to which the front line supervisor's commitment (WILL) was realized. Analysis of nonconformances can then lead back to root causes, so improvement can be made in future performance. Measuring performance at the Last Planner level does not mean you only make changes at that level. Root causes of poor plan quality or failure to execute planned work may be found at any organizational level, process or function. PPC analysis can become a powerful focal point for breakthrough initiatives.

The first thing needed is identification of reasons why planned work was not done, preferably by front line supervisors or the engineers or craftsmen directly responsible for plan execution. Reasons could include:

- Faulty directives or information provided to the Last Planner; e.g. the information system incorrectly indicated that information was available or that prerequisite work was complete.
- Failure to apply quality criteria to assignments; e.g. too much work was planned.
- Failure in coordination of shared resources; e.g. lack of a computer or plotter.
- Change in priority; e.g. workers reassigned temporarily to a "hot" task.
- Design error or vendor error discovered in the attempt to carry out a planned activity.

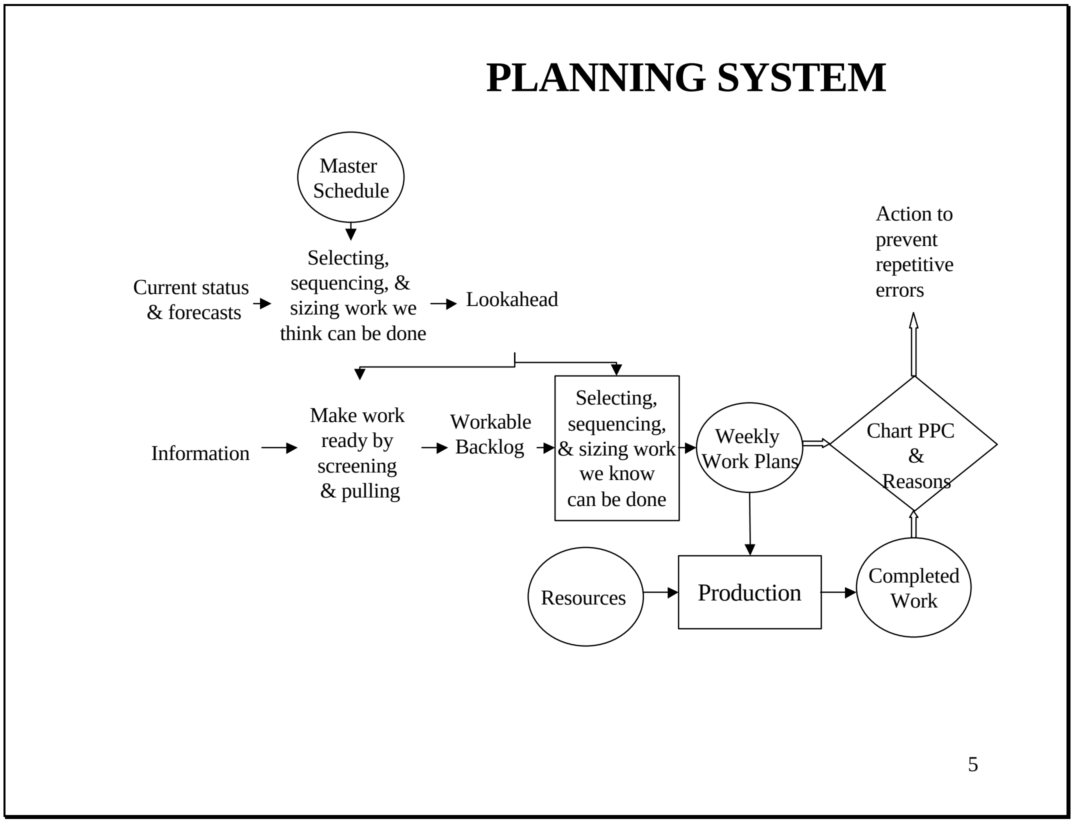
This provides the initial data needed for analysis and improvement of PPC, and consequently for improving project performance.

3.4 Work Flow Control

Here we turn to the topic of work flow control; i.e., causing work to move between production units in a desired sequence and rate. Production Unit Control coordinates the execution of work *within* production units such as construction crews and design squads. Work Flow Control coordinates the flow of design, supply, and installation *through* production units.

In the hierarchy of plans and schedules, the lookahead process has the job of work flow control. Lookahead schedules are common in current industry practice, but typically perform only the function of highlighting what SHOULD be done in the near term. In contrast, the lookahead process within the Last Planner system serves multiple functions, as listed in Table 3.1. These functions are accomplished through various specific processes, including activity definition, constraints analysis, pulling work from upstream production units, and matching load and capacity, each of which will be discussed in the following pages.

Figure 3.2



Last Planner System with Lookahead Process highlighted

The vehicle for the lookahead process is a schedule of potential assignments for the next 3 to 12 weeks. The number of weeks over which a lookahead process extends is decided based on project characteristics, the reliability of the planning system, and the lead times for acquiring information, materials, labor, and equipment. Tables 3.2 and 3.3 are examples of construction and engineering lookahead schedules, respectively. The lookahead schedule is not a simple drop out from the master schedule. Indeed, it is often beneficial to have the team that is to do the work in the next phase of a project collectively produce a phase schedule that serves to coordinate actions that extend beyond the lookahead window (the period of time we choose to look ahead).

Table 3.1

Functions of the Lookahead Process • **Shape work flow sequence and rate** • **Match work flow and capacity** • **Decompose master schedule activities into work packages and operations** • **Develop detailed methods for executing work** • **Maintain a backlog of ready work** • **Update and revise higher level schedules as needed.**

Functions of the Lookahead Process

Prior to entry into the lookahead window, master schedule or phase schedule activities are exploded into a level of detail appropriate for assignment on weekly work plans, which typically yields multiple assignments for each activity. Then each assignment is subjected to constraints analysis to determine what must be done in order to make it ready to be executed. The general rule is to allow into the lookahead window, or allow to advance from one week to the next within the lookahead window, only activities that can be made ready for completion on schedule. If the planner is not confident that the constraints can be removed, the potential assignments are retarded to a later date.

Figure 3.3 is a schematic of the lookahead process, showing work flowing through time from right to left. Potential assignments enter the lookahead window 6 weeks ahead of scheduled execution, then move forward a week each week until they are allowed to enter into workable backlog, indicating that all constraints have been removed and that they are in the proper sequence for execution. If the planner were to discover a constraint (perhaps a design change or acquisition of a soils report) that could not be removed in time, the assignment would not be allowed to move forward. The objective is to maintain a backlog of sound work, ready to be performed, with assurance that everything in workable backlog is indeed workable.[13] Weekly work plans are then formed from workable backlog, thus improving the productivity of those who receive the assignments and increasing the reliability of work flow to the next production unit.

Table 3.2

PROJECT: Pilot	**5 WK LOOKAHEAD**				
ACTIVITY	1/13/97	1/20/97	1/27/97	2/3/97	**NEEDS**
	M T W T F S	**M T W T F S**	**M T W T F S**	**M T W T F S**	
Scott's crew					
"CUP" AHUs-10 CHW, 2 HW	X X X X X	X X X X X	X X X X X		CHW delivers 1-8-97 thru 1-13. HW delivers 1-20.
Punch, label, & tag AHUs			x x x		Materials on site
Ron's crew					
DI Steam to Humidifier	x x x				Materials on site
DI Steam Blowdown	x x				Check material
DI Steam Cond. to coolers (13)		x x x x x	x x x x x	x x x	Material on site
Charles' crew					
200 deg HW 1-"H"	x x x				Matl delivery 1-8-97
200 deg HW 1-"B" & 1-"D"		x x x x x	x x x x x		Release matl for 1-15-97
1st flr 200 deg HW guides & anchors	x x x x x		x x x x x		Material on site. Need West Wing flr covered.
Richard's crew					
2-"A" HW & CHW	x x x x x				Control valves for added VAV coils
CHW in C-E-G tunnels	x x x x x	x x x x x	x x x x x		Need tunnels painted & release materials
Misc FCUs & cond. drains in "I", "J", & "K" 1st flr		x x x x x	x x x x x		Take off & order materials
Punch, label & tag		x x x x x	x x x x x		Material on site

Construction Lookahead Schedule[14]

13 Deliberately building inventories, inventories of ready work in this case, may seem contradictory to the goals of just-in-time. To clarify, inventories of all sort are to be minimized, but as long as there is variability in the flow of materials and information, buffers will be needed to absorb that variability. Reducing variability allows reduction of buffer inventories.

14 The "5 Week Lookahead Schedule" excludes the week covered by the Weekly Work Plan, so shows only 4 weeks.

3.4.1 CONSTRAINTS ANALYSIS

Once assignments are identified, they are subjected to constraints analysis. Different types of assignments have different constraints. The construction example in Table 3.4 lists contract, design, submittals, materials, prerequisite work, space, equipment, and labor; plus an open-ended category for all other constraints. Other constraints might include permits, inspections, approvals, and so on. Design constraints can virtually be read from the Activity Definition Model: clarity of directives (level of accuracy required, intended use of the output, applicable section of code), prerequisite work (data, evaluations, models), labor and technical resources. We previously met these constraints in the discussion of Production Unit Control; then as reasons for failing to complete assignments on weekly work plans.

Table 3.3

Engineering Lookahead Schedule

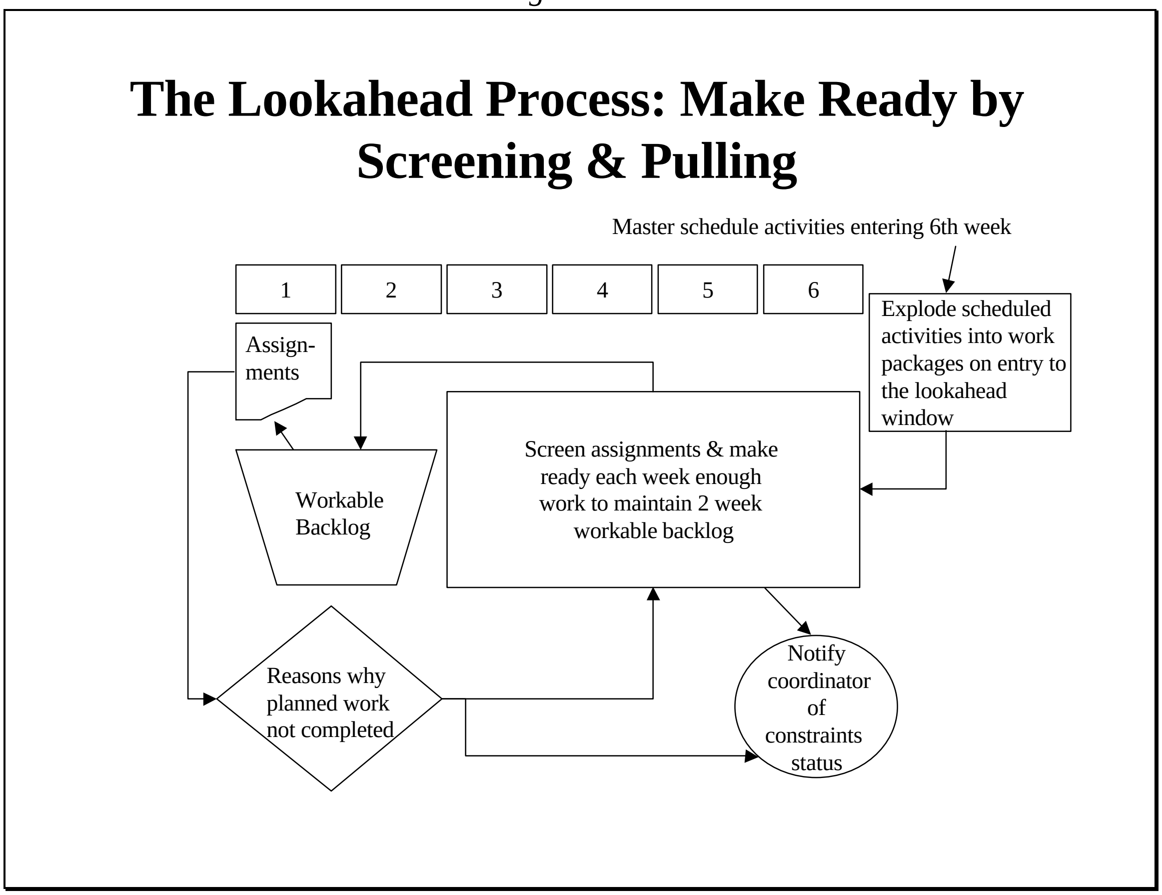
Project:
Discipline: Process
Planner: s
Checked By: x
Prep. Dt: 3/14/02

Activity	Week Ending: 3/28/02					Week Ending: 4/4/02					Week Ending: 4/11/02					Week Ending: 4/18/02					OUTSTANDING NEEDS
	M	T	W	T	F	M	T	W	T	F	M	T	W	T	F	M	T	W	T	F	
Provide const support (Q & A)			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	Need questions from subs.
Review submittal(s)						x	x														Need submittals from sub.
Aid with tool install dsgn effort.		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	Frozen layout, pkg 1 dwgs.
Design drains from tools to tunnel tie-ins.			x	x	x																Frozen layout, input from tool install on installation preferences
Help layout people complete a layout that will work well with tool install routing and drains into the tunnel.	x	x																			Correct tool list.
Complete Pkg 2 specifications							x	x	x	x	x										Final eqpt and mtl usage from mech & tool install.
Create work plans					x					x					x					x	
Send package to QA/QC reviewer for drain design review																	x	x			Final design dwgs for drains; plot time
Start/complete QA/QC review																			x	x	Set of Package 2 review docs, dwgs

Engineering Lookahead Schedule

Constraints analysis requires suppliers of goods and services to actively manage their production and delivery, and provides the coordinator with early warning of problems, hopefully with sufficient lead time to plan around them. In the absence of constraints analysis, the tendency is to assume a throw-it-over-the-wall mentality; to become reactive to what happens to show up in your in-box or laydown yard.

Figure 3.3



Make Ready by Screening and Pulling

3.4.2 Pulling

Pulling is a method of introducing materials or information into a production process. The alternative method is to <u>push</u> inputs into a process based on target delivery or completion dates. Construction schedules have traditionally been push mechanisms, seeking to cause intersections in the future of interdependent actions.

Table 3.4

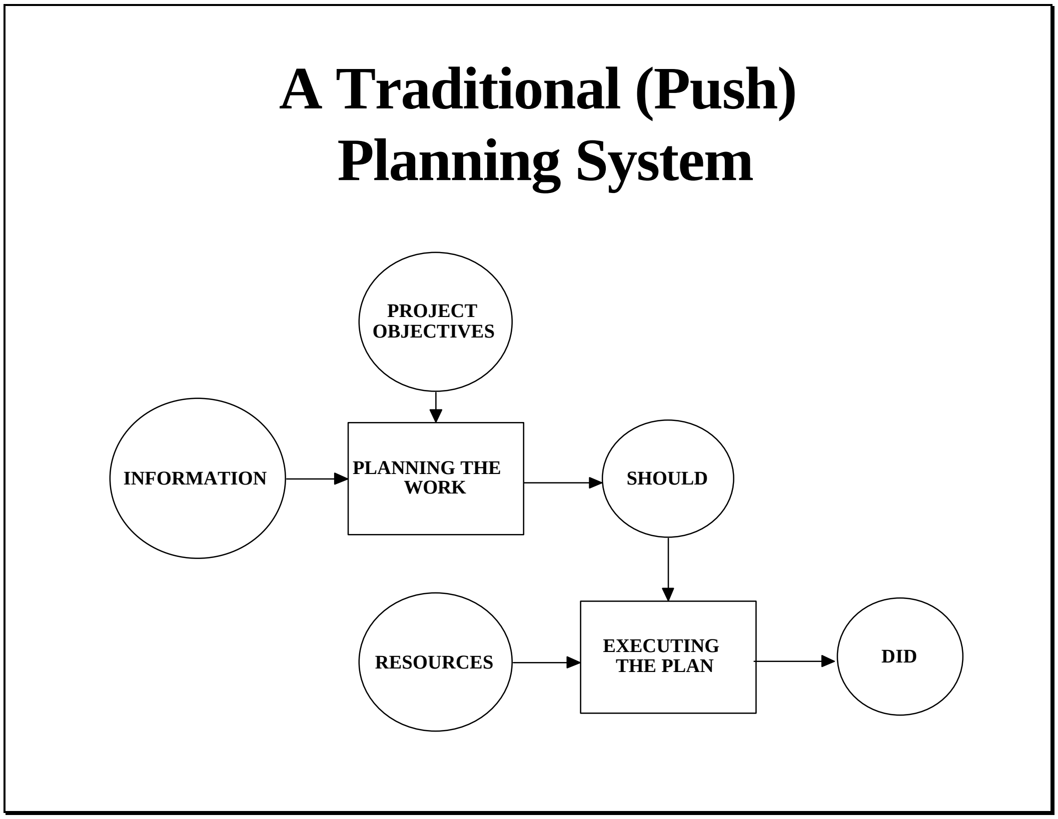
Screening Assignments: Statusing Constraints

ID	Activity	Start	Contract	Design	Submittals	Materials	Pre-Requisite	Space	Equipment	Labor	Other
260	Small Interior Wall Forms Lines 4-M.8, 3-M, 3-K, 4-K.8, 3-H	2/9/98	OK	RFI 68	OK	OK	rebar	OK	OK	OK	None
310	Large Interior Wall Line L Form	2/9/98									
700	Interior Small Walls 3F and 3D Forms	2/9/98									
1142	Small Interior Wall Forms Lines 5-M.8, and 5-K.8	2/9/98									
170	East Wall Between Lines 2 and 6 Line Double Up	2/13/98									
720	Interior Small Walls 3F and 3D Double-up	2/13/98									
1146	Small Interior Walls Lines 5-M.8, and 5-K.8 Double-up	2/13/98									
322	Large Interior Wall Line L Doubleup	2/16/98									
290	Small Interior Walls Lines 4-M.8, 3-M, 3-K, 4-K.8, 3-H Double-up	2/17/98									
735	Interior Small Walls 3F and 3D Strip	2/18/98									

Constraints Analysis

By contrast, pulling allows materials or information into a production process only if the process is capable of doing that work. In our Last Planner system, conformance of assignments to quality criteria constitute such a check on capability. Further, making assignments ready in the lookahead process is explicitly an application of pull techniques. Consequently, Last Planner is a type of pull system.

Figure 3.4



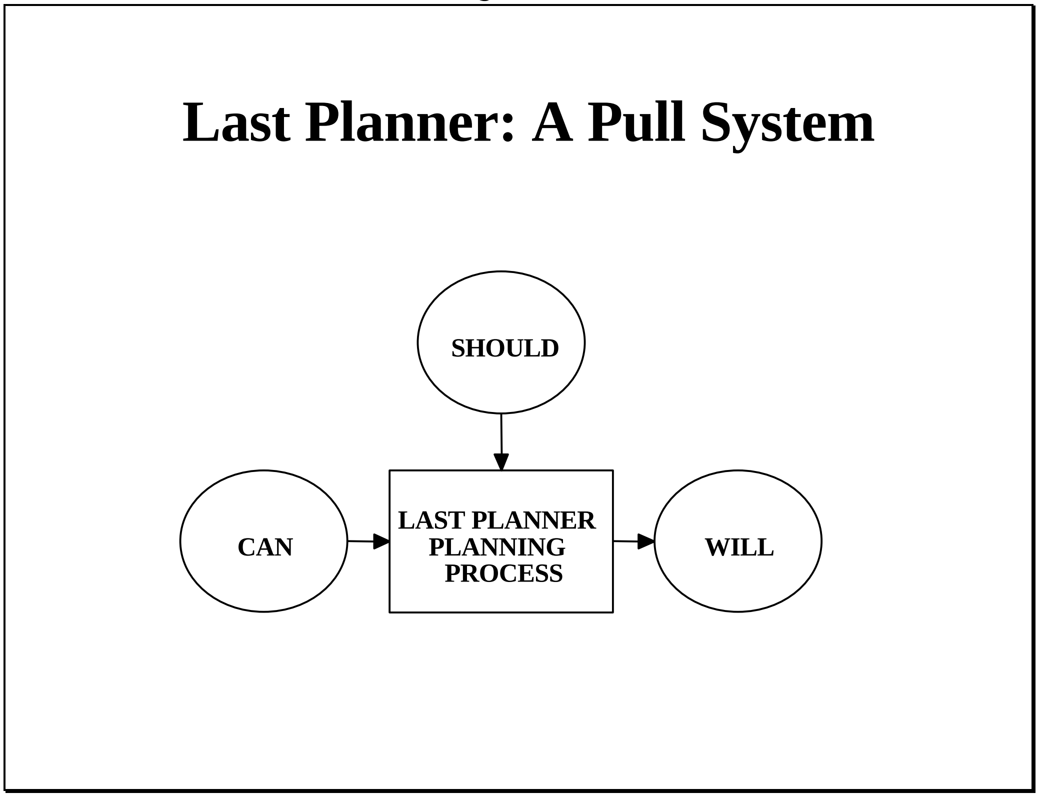
A Traditional (Push) Planning System

Certain things have long been pulled as opposed to pushed; e.g., concrete. With its short shelf life, concrete cannot be ordered too far in advance of need. Fortunately, the lead time[15] for concrete is short, so it is usually possible to wait until you know when it will be needed before ordering it.

Generally, a window of reliability greater than supplier lead time is needed in order for pulling to be most effective. Otherwise, the pulled items may not match up with the work to which they are to be applied. In the industry now, supplier lead times are for the most part much greater than our accurate foresight regarding work completion, hence perhaps a reason for the infrequent use of pulling mechanisms.

[15] Lead time is the time in advance of delivery one must place an order. It is often referred to as "supplier lead time".

Figure 3.5



Last Planner: A Pull System

3.4.3 MATCHING LOAD AND CAPACITY

Matching load to capacity within a production system is critical for productivity of the production units through which work flows in the system, and is also critical for system cycle time, the time required for something to go from one end to the other.

Along with its other functions, the lookahead process is supposed to maintain a backlog of workable assignments for each production unit (PU). To do so requires estimating the load various chunks of work will place on PUs and the capacities of PUs to process those chunks of work. Current estimating unit rates, such as the labor hours required to erect a ton of steel, are at best averages based on historical data, which are themselves laden with the tremendous amounts of waste imbedded in conventional practice. When load and capacity are estimated, are we assuming 30% resource utilization or 60%? What assumptions are being made about variation around averages? Can we expect actual unit rates to fall short of the average half the time? Clearly we need much more accurate data than is typically available.

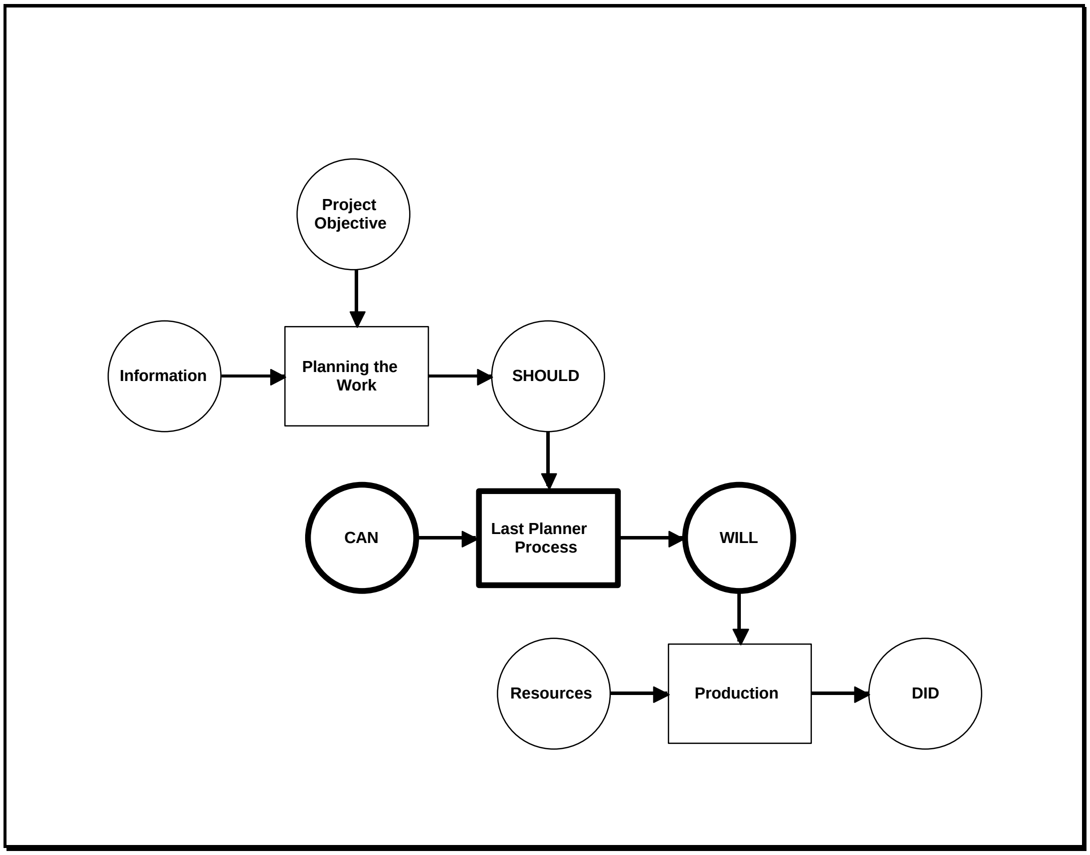
Whatever the accuracy of load and capacity estimates, the planner must still make some adjustments. Either load can be changed to match capacity, capacity can be changed to match load, or, more commonly, a combination of the two. Given the advantages of maintaining a stable work force and avoiding frequent changes, the preference is often for adjusting load. However, that will not be the case when there are pressures to meet scheduled milestones or end dates.

Load can be changed to match capacity by retarding or accelerating work flow. Capacity can be changed to match load by reducing or increasing resources. Pulling helps balance load to capacity because the PU can request what it needs and in the needed amounts.

3.4.4 THE LAST PLANNER SYSTEM AS A WHOLE

Last Planner adds a production control component to the traditional project management system. As shown in Figure 3.6, Last Planner can be understood as a mechanism for transforming what SHOULD be done into what CAN be done, thus forming an inventory of ready work, from which Weekly Work Plans can be formed. Including assignments on Weekly Work Plans is a commitment by the Last Planners (foremen, squad bosses) to what they actually WILL do.

Figure 3.6



The Last Planner System

3.5 A Brief History of the Last Planner System of Production Control

The functions of production management systems are planning and control. Planning establishes goals and a desired sequence of events for achieving goals. Control causes events to approximate the desired sequence, initiates replanning when the established sequence is either no longer feasible or no longer desirable, and initiates learning when events fail to conform to plan (Ballard, 1998). When environments are dynamic and the production system is uncertain and variable, reliable planning cannot be performed in detail much before the events being planned. Consequently, deciding what and how much work is to be done next by a design squad or a construction crew is rarely a matter of simply following a master schedule established at the beginning of the project. How are such decisions made and can they be made better? These questions were the drivers of initial research in the area of production unit level planning and control under the title of the "Last Planner System", a summary report of which is included in Ballard and Howell (1997).

A key early finding was that only about half of the assignments made to construction crews at the beginning of a week were completed when planned. Experiments were performed to test the hypothesis that failures were in large part a result of lack of adequate work selection rules (these might also be called work release rules). Quality criteria were proposed for assignments regarding definition, sequence, soundness, and size. In addition, the percentage of assignments completed was tracked (PPC: percent plan complete) and reasons for noncompletion were identified, which amounted to a requirement that learning be incorporated in the control process.

Definition: Are assignments specific enough that the right type and amount of materials can be collected, work can be coordinated with other trades, and it is possible to tell at the end of the week if the assignment was completed?

Soundness: Are all assignments sound, that is: Are all materials on hand? Is design complete? Is prerequisite work complete? Note: During the plan week, the foreman will have additional tasks to perform in order to make assignments ready to be executed, e.g., coordination with trades working in the same area, movement of materials to the point of installation, etc. However, the intent is to do whatever can be done to get the work ready before the week in which it is to be done.

Sequence: Are assignments selected from those that are sound in the constructability order needed by the production unit itself and in the order needed by customer processes? Are additional, lower priority assignments identified as workable backlog, i.e., additional quality tasks available in case assignments fail or productivity exceeds expectations?

Size: Are assignments sized to the productive capability of each crew or subcrew, while still being achievable within the plan period? Does the assignment produce work for the next production unit in the size and format required?

Learning: Are assignments that are not completed within the week tracked and reasons identified?

As a result of applying these criteria, plan reliability (the percentage of assignments completed) increased, and with it, crew productivity also increased (Ballard and Howell, 1997)[16].

The use of explicit work selection rules and quality criteria for assignments was termed "shielding production from upstream uncertainty and variation." (Ballard and Howell 1994) Such shielding assures to a large degree that productive capacity is not wasted waiting for or looking for materials and such. However, because of its short term nature, shielding cannot avoid underloading resources when work flow is out of sequence or insufficient in quantity. Further, reasons for failing to complete planned assignments were dominated in most cases by materials-related problems. Consequently, a second element of the Last Planner System was created upstream of weekly work planning to control work flow and to make assignments ready by proactively acquiring the materials and design information needed, and by expediting and monitoring the completion of prerequisite work (Ballard, 1997).

The tool for work flow control was lookahead schedules. The construction industry commonly uses lookahead schedules to focus supervisors' attention on what work is supposed to be done in the near future. Experiments in work flow control were performed using lookahead schedules in a very different way than had been traditional. A

[16] On the whole, improvements tended to be from PPC levels around 50% to the 65-70% level, with a corresponding increase of 30% in productivity. Productivity improvement has ranged from 10% to 40%+. It is hypothesized that these differences result from different initial resource utilization levels. For example, if initial utilization is 50%, corresponding to a PPC of 50%, then increasing PPC to 70% is matched with an increase in utilization to 65%, which amounts to a 30% improvement in productivity.

set of rules was proposed for allowing scheduled activities to remain or enter into each of the three primary hierarchical levels of the scheduling system:

- Rule 1: Allow scheduled activities to remain in the master schedule unless positive knowledge exists that the activity should not or cannot be executed when scheduled.
- Rule 2: Allow scheduled activities to remain in the lookahead window only if the planner is confident that the activity can be made ready for execution when scheduled.
- Rule 3: Allow scheduled activities to be released for selection into weekly work plans only if all constraints have been removed; i.e., only if the activity has in fact been made ready.

In addition, a set of objectives was proposed for the lookahead process:

- Shape work flow sequence and rate
- Match work flow and capacity
- Decompose master schedule activities into work packages and operations
- Develop detailed methods for executing work
- Maintain a backlog of ready work

Lookahead windows are structured such that week 1 is next week, the week for which a weekly work plan is being produced. Week 2 is two weeks in the future. Week 3 is three weeks in the future, and so on. Early data indicated that plans as close to scheduled execution as Week 2 only contained about half the assignments that later appeared on the weekly work plans for that week. Week 3's percentage was only 40% (Ballard, 1997). Failures to anticipate assignments appear to result in large part from lack of detailed operations design and consequently could be remedied by incorporating detailed operations design into the lookahead process (see *First Run Studies* in the Glossary of Terms)..

While some operations design can be performed once the type of operation and its general conditions are known, detailed design (certainly of construction operations) cannot be done until certain additional information is available; i.e., information regarding material staging areas, adjacent trades, competing claims on shared resources, which individuals will be assigned to the work, etc. Consequently, detailed operations design should be performed within the lookahead window, close in time to the scheduled start of the operation. It is provisionally assumed that this timing requirement applies also to design activities, but this will be subject to research findings.

3.6 Previous Applications of the Last Planner System to Design

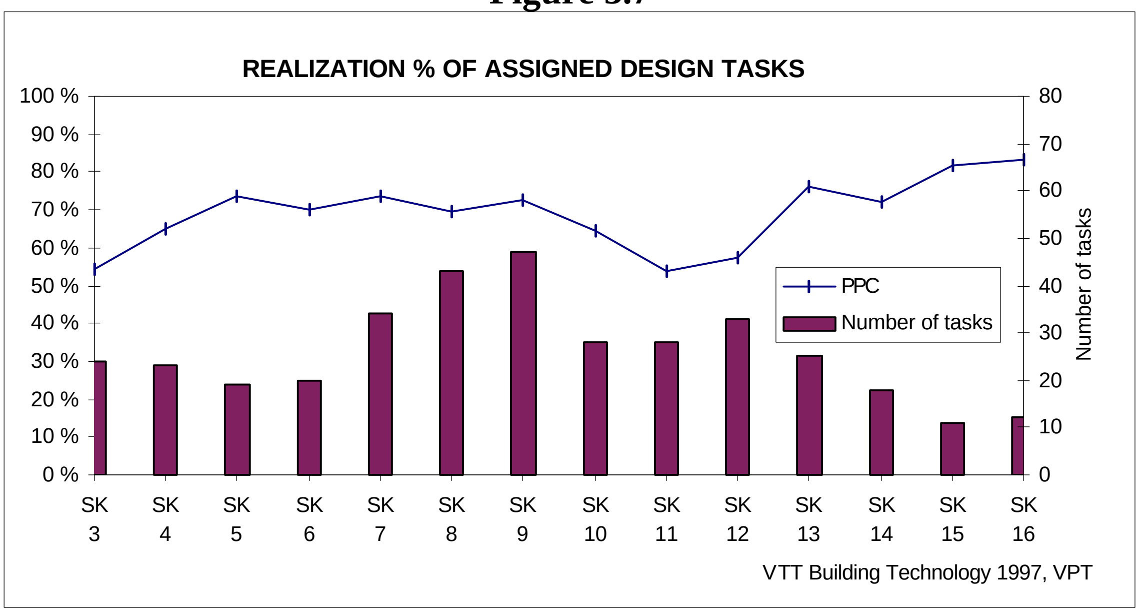
Previous to the research reported in this dissertation, the Last Planner System had not been applied in full to design production control. However, elements of the Last Planner System have previously been applied to the management of production during the design phase of projects. Koskela et al (1997) report that the traditional method of design management on their test project was incapable of producing quality assignments, and described the traditional method as follows:

> *"A drawing due date schedule, and a summary drawing circulation list form the basis of design management. There are design meetings every two weeks or so, where a contractor representative (site manager) acts as the chairman. The contractor may also organize meetings to address specific problems between design disciplines.*
>
> *Thus, the primary control set is to reach the drawing due dates. Instead the order or timing of individual design tasks is not scheduled, but are left for self-management by the design team. In practice, the design tasks to be executed or input information needed are discussed in the weekly design meetings. However, this procedure is not perfect. There is no effective follow-up of decided action, and only a part of output due is often available. It seems that often parties come unprepared to the meeting. Design decisions are often made in improvized style, and decisions taken are not always remembered in next meetings."* (p. 9)

Among the improvement actions taken was progressive detailing of the schedule (in one month chunks), documentation of input information needs reported in design meetings, explicit commitment of design supervisors to tasks in the next few weeks, monitoring of assignments completed, and identification of reasons for noncompletion. As a result, PPC soon rose to the 70% level. (The negative dip in design meetings [SK] 10-12 resulted from a major design change.) The design time for the building was 30% under the standard time for the type of building and participants rated the method favorably, as shown in Figure 3.7.

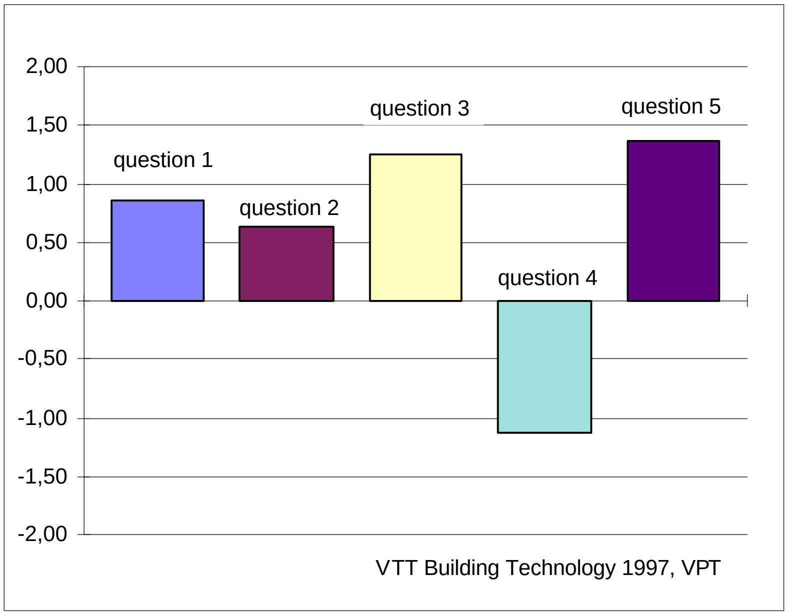
Miles (1998) reports a more complete and extensive implementation of the Last Planner System, which included the lookahead process. Overall PPC averaged around 75%, design was completed approximately 10% earlier than anticipated, and design costs were reduced by 7%. The research also replicated in design earlier findings in construction (Howell, 1996) regarding the prevalence of plan quality failures. They found that failures to complete assignments were divided in a ratio of 2 to 1 between internal impacts they potentially could control and external impacts over which they had little or no control.

Figure 3.7



PPC (Koskela et al, 1997)

Figure 3.8



The average replies, on a scale of -2 to 2, to the questions :
1. *Was the availability of input data improved?*
2. *Was the decision making in design process improved?*
3. *Did the method yield benefits?*
4. *Was it laborious to work according to the method?*
5. *Should the method be used in the next project?*

Participant Survey (Koskela et al, 1997)

3.7 Evaluation of Last Planner against Criteria for Production Control Systems

The criteria proposed in the previous chapter were:

- *Variability is mitigated and remaining variability managed.*
- *Assignments are sound regarding their prerequisites.*
- *The realization of assignments is measured and monitored.*
- *Causes for failing to complete planned work are investigated and those causes are removed.*
- *A buffer of sound assignments is maintained for each crew or production unit.*
- *The prerequisites of upcoming assignments are actively made ready.*
- *The traditional schedule-push system is supplemented with pull techniques.*
- *Design production control facilitates work flow and value generation.*
- *The project is conceived as a temporary production system.*
- *Decision making is distributed in design production control systems.*
- *Design production contro resists the tendency toward local suboptimization.*

That the Last Planner system of production control conforms to these criteria and principles should be apparent. It is explicitly dedicated to the reduction and management of variability. One of the quality criteria for assignments is soundness. PPC measurement is central. Reasons for plan failure are tracked and analyzed. The lookahead process has the explicit purpose of maintaining a buffer of sound tasks and also actively makes scheduled tasks sound and facilitates work flow and value generation. Pulling is evident both in the assignment quality criteria and in the make ready function within the lookahead process. The framework for Last Planner is the conception of projects as temporary production systems. Distributed decision making is evident in the requirement that only quality assignments be accepted and also in the work flow control decisions to be made within the lookahead process. And, finally, Last Planner resists the tendency toward local suboptimization in its application of the criterion 'sequencing', applied both in lookahead planning and to weekly work plan assignments.

3.8 Research Questions

This new production planning and management method has been in development since 1992 (Ballard & Howell 1997). It has been successfully used in a series of projects ranging from oil refineries to commercial building construction. Hitherto it has been used primarily in site construction, rather than in design and engineering and its implementation has generally resulted in an improvement of work flow reliability, as measured by percent plan complete, to 65-70% PPC. The questions driving this research are: 1) *What can be done by way of tools provided and improved implementation of the Last Planner system of production control to increase plan reliability above the 70% PPC level? 2) How/Can Last Planner be successfully applied to increase plan reliability during design processes ?*

It is intuitively obvious that making work flow more reliable (predictable) can reduce the cost or duration of the total project. When the numerous specialists can rely on delivery of calculations, drawings, materials, and prerequisite work from other specialists, both within and outside the project team, they are better able to plan their own work, and better planning yields better performance. All else being equal, with greater flow reliability should come more efficient production, less wasted effort and rework, and better matching of resources to tasks. Even partial and limited improvements in work flow reliability have demonstrated schedule and cost improvements (Koskela et al., 1997 and Miles, 1998).

It is also apparent that construction benefits from greater reliability in the flow to the construction site of information and materials. The impact of more reliable flow of design information on project cost and duration is much greater in the construction phase of projects than in design. When constructors can take action in advance of receiving design information that coordinates the flow of labor and equipment, material deliveries, and completion of prerequisite work, the project runs more smoothly and efficiently. We have numerous instances from construction processes showing the benefits of increasing material and information flow reliability even within the job site itself (Ballard, et al, 1996; Ballard and Howell, 1997).

Consequently, it is appropriate to focus the research question on improving work flow reliability, with confidence that improving reliability is beneficial to project performance. Subsequent research may seek to refine and quantify these causal relationships, but the current research needed is to establish more effective methods for production control in general and to extend production control techniques to design.

CHAPTER FOUR: RESEARCH METHODOLOGY

4.1 Introduction

This thesis is about engineering management, not about epistemology. However, some epistemological assumptions lie behind any attempt to add to knowledge, in whatever field. Making those assumptions explicit allows the reader to better understand and assess claims and inferences. The purpose of this introduction is to clarify epistemological assumptions. Three issues will be addressed: 1) To what field of knowledge is this thesis proposing to contribute? 2) Difficulties associated with competing paradigms in the field. 3) The research strategy and methods used in this thesis.

4.1.1 ENGINEERING MANAGEMENT AS A FIELD OF STUDY

The topic of this thesis is engineering management, which is assumed to belong to the general field of technology rather than science. Roozenburg and Eeckels propose that technology and science pursue different goals through different processes or methodologies (Roozenburg and Eeckels, 1995, pp. 32-35). Science pursues knowledge acquisition, while "technology-the design, making, and using of artifacts-is a systematized form of action." Both can be pursued methodically. For both, certain rules have been developed, the observance of which is supposed to "…contribute to efficient performance of the activity involved." Both processes involve reasoning. Which conditions should these two different reasoning processes meet, so they can claim reliability, meaning that the conclusions to which they lead are correct or true? The criterion for reliability of scientific reasoning is the truth of the resulting statements. The criterion for reliability of technological reasoning is the effectiveness of the action process, based on that reasoning. Of course we may pose a ‘scientific question’ about a technological claim: ‘Is it indeed true that the proposed action will be effective?’ That is precisely the type of question posed in this thesis. ‘Is it true that implementing a specific set of policies and techniques collectively called “the Last Planner system of production control” improves the reliability of work flow?’

Given this ‘scientific’ question about a technological matter, what methodological rules are appropriate? What kind of data is needed to answer the question and what kind of inferences can we expect to make from such data? Many engineering management theses pose claims about some aspect of engineering management action, use surveys to collect data regarding same, then apply statistical analyses to test the adequacy of their claim. This methodology works from a sample of a population to claims about the population itself by statistical generalization. ‘If 79% of a 151 member sample report that they include safety records in their prequalification of contractors, what generalization can I make regarding all members of the population that prequalifies contractors?’ Rules of statistical generalization exist for answering such questions.

However, statistical generalization from sample to population is an appropriate methodology in the field of engineering management only if one is interested in testing claims about current behavior. If the objective is to introduce new policies and behaviors with the intent of improving engineering management practice, a different type of methodology is needed. The world of engineering management practice may well be void of practitioners following the proposed new policies and techniques, so there is no sample to take. The question is not ‘How many people employ the Last Planner system and with what effect?' What's needed is a type of experiment rather than a survey[17]. The relevant question has the form 'Will the desired consequences result from taking the proposed action?'

What type of 'experiment' is needed to pursue the research questions: 1) What can be done by way of tools provided and improved implementation of the Last Planner system of production control to increase plan reliability as measured by Percent Plan Complete? 2) How/Can Last Planner be successfully applied to increase plan reliability during design processes**?** As is said in the States, "experiment" is a loaded term. Scholars differentiate between so-called 'true' experiments and quasi-experiments (Campbell and Stanley, 1966). Some propose that case studies be conceived as a type of experiment, having similar methodological rules (Yin, 1994). No position is taken here regarding these matters except that some type of experiment is the appropriate methodology for the type of research question posed as distinct from a survey of current practice. 'Experiment' is conceived in practical terms to mean acting in the world with an intended effect. As with all experiments, the researcher must be open to learning more or different things than expected. As with all experiments, generalization from findings is problematic.

Experiments don't prove conclusions in the sense of logical deduction even in the field of natural science. Experimental reasoning is a type of reductive reasoning from particular to general quite unlike either formal logical reasoning or statistical generalization. Everything depends on the specifics of given situations. What are the

[17] Surveys may be used in conjunction with an experiment or a case study devoted to implementation of a policy. For example, one could survey participants for opinions regarding the effectiveness of the policy. The point here is that survey cannot be the principal or primary research strategy for conducting policy evaluation.

relevant variables and to what extent can they be controlled? Some experiments in natural science can approximately isolate one (set of) variable(s) from others and so argue more persuasively that 'things don't burn in the absence of oxygen.' However, even that extreme type of argument depends essentially on the cohesion and consistency of theories. As long as the phlogiston theory held sway, oxygen was invisible to the mind's eye (Kuhn, 1962). Generalization from experiments is fundamentally a matter of telling a good story; i.e., having a good theory.

4.1.2 COMPETING ENGINEERING MANAGEMENT PARADIGMS

According to Thomas Kuhn, in his *The Structure of Scientific Revolutions* (1962), theories emerge from paradigms, which are fundamental propositions and assumptions about the subject matter that tend to remain implicit except in periods when paradigms change. It could be argued that engineering management is currently in just such a period of paradigm shift. In such periods, communication becomes even more perilous than normal because the community of researchers and practitioners no longer share a common language and presuppositions. The research question posed in this thesis belongs to an emerging engineering management paradigm, in conflict with the prevailing paradigm. Consequently, care must be taken lest the change in language and presuppositions hinder the reader. That can best be done by making changes in language and presuppositions explicit. Recognizing that paradigm shifts are periods of intellectual conflict, it is not expected that all readers will accept the proposed changes.

In the midst of a paradigm shift, it is difficult and perhaps impossible to clearly delineate the boundaries of the opposed camps. The conflict is itself producing that delineation, at the conclusion of which the vanguished disappears into the sands of time and the victor rides forward toward its own inevitable yet incomprehensible future defeat. Nonetheless, an effort is required to clarify ‘where all this is coming from.’

The conflict in engineering management was presented in Chapter Two as an opposition between those who adopt the view of production (the design and making of physical artifacts) as transforming or converting inputs into outputs and those who add the flow and value views. At first glance, this hardly appears to belong in the same league as the shift from a geocentric to a heliocentric cosmology—perhaps the most famous example of a paradigm shift. Nonetheless, the shift from the conversion to the flow and value views is enormously important. A prime example is variability, which is itself virtually invisible from the conversion-only view. Manufacturing has taken the lead in the development of production theory, yet according to manufacturing theorists, “…variability is not well understood in manufacturing….” (Hopp and Spearman, 1996, p. 311) One can only assume that variability is even less well understood in the AEC industry, where it would seem to be even more an issue. From a pure conversion view, variability is managed primarily through the provision of schedule and cost contingencies at the global level of projects, but is neglected in the structuring of work flows and operations. Once contracts are let, variability ‘officially’ appears only in the form of failure to meet contractual obligations.

Closely related to the conversion/flow distinction is that between project and production management. Project management concepts and techniques are oriented to the determination of project objectives and the means for achieving them (planning), then to monitoring progress toward those objectives (control). This is a highly abstract perspective, appropriate to any endeavour that is goal-driven and time-limited; i.e., to projects. Unfortunately, project management concepts and techniques are employed in attempts to manage production processes that take on project form without regard to the specific nature of the projects and production to be managed. This is the more unfortunate as many projects involve production; i.e., designing and making things. Management of production projects requires the use of production management concepts and techniques, which in turn are derivative from the conversion/flow/value views.

Is variability in processing times, arrival rates, errors, and breakdowns visible to those comfortable with the project management/conversion paradigm? Such matters might be considered to belong to 'mere' production; to be in the province of the engineering or construction crafts rather than a matter for management. For such readers, the research questions posed in this thesis may well appear either trivial or irrelevant.

4.2 Research Design

4.2.1 RESEARCH QUESTION

Prior to selecting a research strategy, it is necessary to determine the research topic, question, and purpose. The topic of this research is engineering management; more specifically, improving control of design and construction processes on architectural/engineering/construction projects. The questions driving this research are: 1) 1) *What can be done by way of tools provided and improved implementation of the Last Planner system of production control to increase plan reliability above the 70% PPC level? 2) How/Can Last Planner be successfully applied to increase plan* *reliability during design processes*[18]*?* The purpose of the research is to evaluate and improve the effectiveness of this managerial policy and practice.

Evaluation is a type of applied or action research (McNeill, 1989), concerned with technology in the broad sense; i.e., goal-oriented action. Evaluations typically pursue improvement of the subject policy or practice in addition to rating effectiveness against objectives. Simple rating is often made more difficult because of changes made mid-stream in the policy or practice being evaluated. Opportunity for improvement seldom waits on the desire for an unambiguous definition of what is to be evaluated. Indeed, evaluation and improvement often blur together, especially when the researcher is involved in the creation and implementation of the policies and practices being implemented and evaluated, as is the case with this researcher and research. Some might worry about an involved researcher's objectivity. On the other hand, it may simply be that technological research demands another concept and procedure than that of traditional, fact finding research.

Evaluation does not fit neatly within the classification of traditional purposes of enquiry; i.e., exploratory, descriptive, explanatory. The conceptual model for technological research appears to have been drawn from the natural sciences, for which the (immediate) goal is rather to understand than to change the world. Policy evaluation involves exploration, description, and explanation, but subordinates those purposes to the overriding purpose of improving practice. Nonetheless, improving practice requires understanding what works and does not work, and to as great an extent as possible, understanding why what works and what does not. Consequently, the purpose of this

[18] In this thesis, the term "design" is used to designate both design and engineering activities; not shaping space to aesthetic criteria.

research includes determining the extent to which the Last Planner system is effective and why it is or is not effective.

4.2.2 RESEARCH STRATEGIES

The three traditional research strategies are experiment, survey, and case study (Robson, 1993, p.40). It has previously been argued in this chapter that a survey strategy is inappropriate for the question posed by this research. The research strategies that could possibly lend themselves to investigation of this research question include true experiments, quasi-experiments, and case studies.

True experiments require establishing a control group that differs in no relevant way from the experimental group. A true experiment was not appropriate because of the difficulty of establishing a control group and lack of control over extraneous variables. At first glance, it would seem to be possible to use a pre-test, post-test, single group design, measuring flow reliability of the same group before and after implementation of the Last Planner system. This approach has several difficulties: 1) Work flow reliability is not an explicit, measured objective of traditional production control systems, so pre-test quantitative data is not available, and 2) our ability to generalize from the experimental results is limited by the possibility that those who choose to try the Last Planner method are somehow different from those who do not so choose. The second difficulty could be managed by conditioning and qualifying the inferences drawn from the experiment. The first difficulty, the lack of quantitative data on flow reliability for the pre-test, could be handled by substituting subjective data, in the form of interview results. However, this is clearly an inferior solution, and so pushes the researcher to find a more effective research strategy.

Quasi-experiments are "…experiments without random assignment to treatment and comparison groups." (Campbell and Stanley, 1966, cited in Robson, 1993, p. 98) They admittedly sacrifice some of the rigor of true experiments, but are nonetheless appropriate for a large range of inquiry, where true experiments are impossible or inappropriate. The key issue regarding quasi-experiments is what inferences can be drawn. It is proposed that inferences be justified in terms of study design, the context in which the study occurs, and the pattern of results obtained (Cook and Campbell, 1979). While this strategy responds to the difficulty of generalizability posed above, it still leaves us without pre-test quantitative data on flow reliability in design, and consequently, is not by itself an adequate strategy for pursuing this research.

Case study is "…a strategy for doing research through empirical investigation of a contemporary phenomenon within its real life context using multiple sources of evidence" (Robson, p. 52). Case studies are an appropriate research strategy when there is little known about the topic of interest, in this case, for example, how production is managed in design; and a change in theory or practice (production control) is proposed (Robson, p.169). Multiple case studies allow the researcher to pursue a progressive strategy, from exploration of a question to more focused examination of trials. Given the policy nature of the research question being posed, a multiple case study strategy seems appropriate.

4.3 Research Methods

4.3.1 DATA COLLECTION

Executing a research strategy requires methods for data collection and analysis. What research methods are available, especially for case studies, the research strategy to be pursued in this thesis? Of those available, which fit best with conditions such as accessibility to people and documents, involvement of the researcher in managerial decision making, time available, etc?

Methods for data collection include direct observation, interviews and questionnaires, and documentary analysis. A variant of direct observation is participant observation; i.e., observational reporting by a researcher who is part of the group being observed.

All these methods of data collection are used in this research. In all cases, the researcher served as a consultant to the project team, and consequently was in the role of participant observer rather than a neutral observer. Specific observational data was collected from participation in project coordination meetings and other events devoted to planning and controlling design and construction processes. Interviews or questionnaires were used in all cases to collect team member assessments, both during the course of each project and at the conclusion of each. Interviews were also used to collect other participants' observations of meetings and events relevant to project control at which the researcher was not present. Records collected included meeting minutes and memos, various forms of schedules, and action item logs. In all cases, measurements were made and recorded of short-term assignments, their due dates, actual completion dates, and reasons for failure to complete assignments on their due dates.

4.3.2 Data Analysis and Evaluation

McNeill (1989) suggests three key concepts: reliability, validity, and representativeness. Reliability concerns the extent to which research can be repeated by others with the same results. "Validity refers to the problem of whether the data collected is a true picture of what is being studied." Representativeness concerns whether the objects of study are typical of others, and consequently, the extent to which we can generalize.

Reliability in action research is inevitably questionable because of the active role played by the researcher in generating the phenomena being studied. Validity of findings is especially difficult in survey research because of the potential difference between what people say and what they do. It is less a problem for action research because of its public nature and the availability of measurement data such as PPC (Percent Plan Complete). Generalizability from the cases is a question that cannot be completely answered, no more than it can for a limited number of laboratory experiments. However, unlike laboratory experiments, policy implementations are made in the messy reality of organizations and social relations. Few if any variables can be completely controlled. In the case of this research, attempts are made to control key variables of implementation and execution of the system. However, it is recognized that control is partial and incomplete. Nonetheless, having demonstrated even on a single project that plan reliability can be improved is sufficient to establish system effectiveness. Future work may be devoted to better understanding the conditions necessary for such success.

Another difficulty is that plan reliability is measured by PPC ('percent plan complete'; i.e., percentage of assignments completed), but PPC does not directly measure plan quality. First of all, success or failure in assignment completion may be a consequence either of the quality of the assignment or of its execution. Since the Last Planner system primarily attempts to improve plan quality, execution failures and therefore PPC may not vary with its effectiveness. In addition, apart from unsound assignments, it is often difficult to differentiate between an execution and a quality failure. Was the assignment poorly defined or was the problem with the lack of effort or skill on the part of the designers or builders?

Yet a further difficulty is the ambiguity of assignment 'completion' when assignments have not been well defined. An assignment to "Produce as many piping drawings as you can by the end of the week" might be marked as completed. The researcher can partially guard against this problem by reviewing assignments for adequate definition. However, it is virtually impossible for the researcher to prevent someone marking assignments completed in order to 'make the worse appear better'. The best defense might be to convince those doing the marking that PPC is not a measure of individual but of system performance. Unfortunately, that is not quite true. Individuals can be better or worse at defining, sizing, sequencing, and assessing the soundness of assignments. PPC records of individual front line supervisors can be revealing of those capabilities.

For these various reasons, evaluating the impact of the Last Planner system on plan reliability is no straightforward matter. Similar difficulties beset improving the system, which occurs through understanding and preventing plan quality failures. It is often difficult to accurately determine reasons for failure. Unsoundness of assignments is the easiest to determine because something is lacking that is needed to do the assignment properly; e.g., a soils report, a stress calculation, a decision between alternative designs, etc. Failures from sizing or sequencing are more difficult to identify. The later case studies incorporate efforts to improve plan failure analysis based on experiences in the previous cases.

4.3.3 CASE STUDIES

The research was done through a series of case studies. The first case, the CCSR project, was an exploratory extension of the Last Planner system to the coordination of multiple trades on a construction project. The primary improvement from that case was the addition of the constraints analysis process. The second case, the Next Stage project, is an exploratory case study on the extension of the Last Planner system to design production control. Case Three shows the efforts of a speciality contractor, Pacific Contracting, to improve its work flow reliability. It may well reveal the limits on a speciality contractor implementing the Last Planner system unilaterally. Case Four, the Old Chemistry Building Renovation project, shows the potential for improvement in work flow reliability from a more thorough and deliberate education and training of the project team. Case Five is the Zeneca Project, one of several implementations of the Last Planner system undertaken by Barnes Construction with significant education and coaching provided to the participants, and application of the latest thinking and techniques in the Last Planner system.

CHAPTER FIVE: CASE ONE-CCSR PROJECT

5.1 Project Description and Last Planner Implementation

The CCSR Project was a laboratory building for Stanford University for which the general contractor was Linbeck Construction. CCSR stood for Center for Clinical Services Research. Prior to CCSR, the Last Planner system of production control had been implemented primarily by contractors doing direct production work. There was some question about how to apply Last Planner to subcontracted projects and how effective that application might be. CCSR was selected as a pilot project to explore feasibility and develop techniques. The specific research question was: *How/Can plan reliability be improved during site construction on largely subcontracted projects?*

The research plan was to introduce the techniques listed below during weekly subcontractor coordination meetings, then measure PPC and track reasons for noncompletion of weekly assignments.[19] In addition to the Last Planner procedures and techniques previously developed, the intent was to do the following:

1. Detailed scheduling by phase[20].
2. Intensive subcontractor involvement in phase scheduling.
3. Collection of status input from subs before the scheduling meeting.
4. Trying to select only tasks each week that are free of constraints.

[19] The author introduced the system to the project and visited periodically during the course of the subsequent three month pilot. Under the author's direction, Abraham Katz, a Stanford graduate student, assisted the project superintendent with scheduling and documentation as part of an independent study performed for Professor Martin Fischer. The author is a consulting professor at Stanford and also at the University of California at Berkeley.

5. Measuring PPC, identifying and acting on reasons.

A weekly planning cycle (Table 5.1) was established that specified who was to do what during each week as regards planning and control. For example, subcontractors were to status their tasks scheduled for the next 3 weeks by noon Monday, so the general contractor (GC) could revise the short interval schedule, which in their case covered a 6 week lookahead period.

Status reporting consisted of completing a constraints analysis form, shown in Table 5.2, which shows selected scheduled tasks for three of the subcontractors on the project. Common constraints on the readiness of scheduled tasks for assignment and execution were included on the form; i.e., contract, design, submittals, materials, prerequisite work, space, equipment, and labor. An open-ended, "other" category was also provided to capture less common constraints. The intention was to focus attention and action on making scheduled tasks ready by removing their constraints.

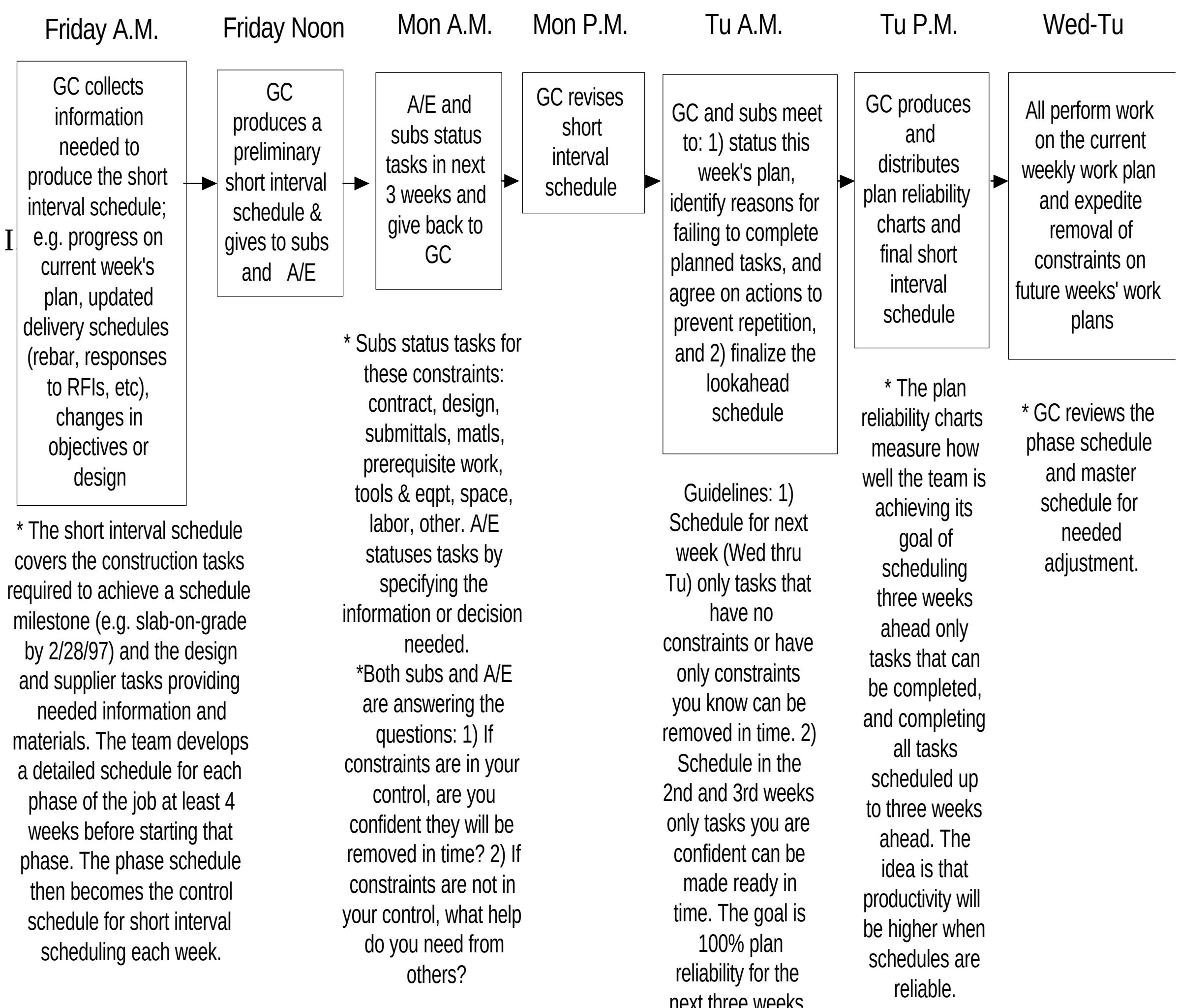
5.2 PPC and Reasons

Several kinds of data were collected: PPC and reasons, auxiliary documents such as phase and master schedules, and the observations of the researcher. PPC and reasons data was collected each week from 12/24/97 through 3/3/98, during the wettest season in the San Francisco area in recorded history. Although the project had taken weatherizing precautions to minimize weather-related delays, such as type of fill material and drainage systems, nonetheless rain was

[20] A phase was conceived in terms of a relatively independent facility system. For example, the first phase-during which this research was conducted-was from

by far the most frequently cited reason for failing to completed assignments on weekly work plans

Table 5.1



CCSR-Weekly Planning Cycle

Table 5.2

CCSR Weekly Planning Cycle

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excavation to slab-on-grade.

Table 5.2

Wills

II. ID	**Activity**	**Start**	**Contract**	**Design**	**Submittals**	**Material**	**Pre-Requisite**	**Space**	**Equipment**	**Labor**	**Other**
950	Tunnel Lobby - Walls Rebar	3/4/98									
1040	Footings 6 & 7 Dowels	3/4/98									
1220	Footings 6 & 7 Between A and H Dowels, and Footings E & G Dowels Between 4.5 and 8	3/4/98									
630	Line 4 Wall and Line C Wall Rebar	3/6/98									
344	Large Interior Wall Line J and H.8 Rebar	3/9/98									
1154	Small Interior Wall Rebar Lines 6-K, and 6-M, 6-P	3/9/98									

Cupertino Electric

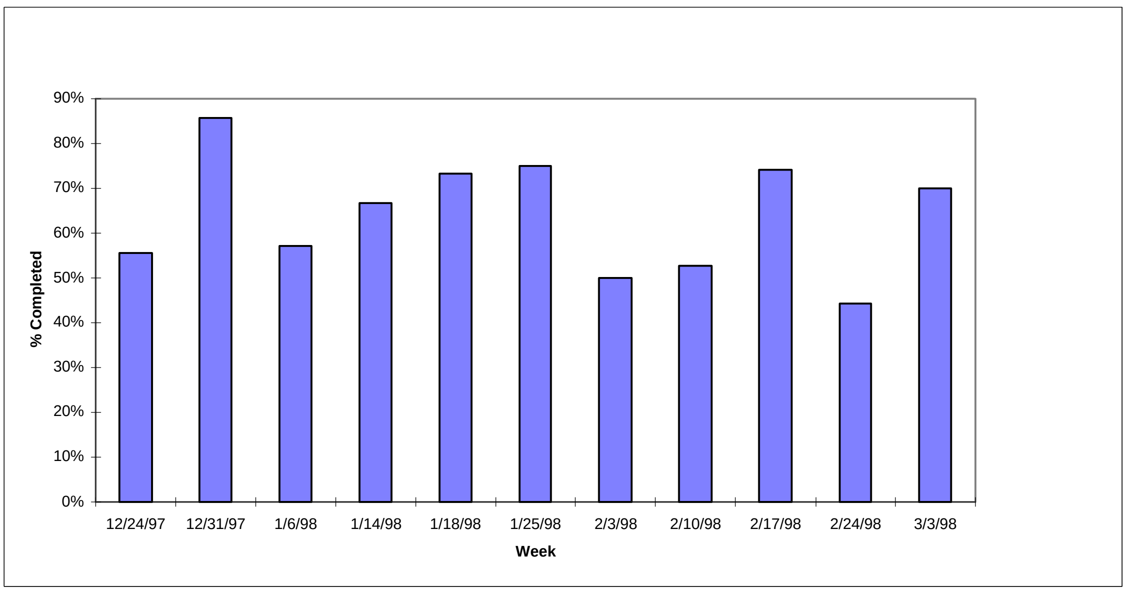
ID	**Activity**	**Start**	**Contract**	**Design**	**Submittals**	**Material**	**Pre-Requisite**	**Space**	**Equipment**	**Labor**	**Other**
402	Inspection	3/4/98									
	Underground Electrical N-W S-W Quadrant	3/5/98									

CCSR-Constraints Analysis Form

PPC was measured as shown in Figure 5.1, ranging from an initial measurement of 56% during the week of 12/24/97 to 70% in the week of 3/3/98. Rain was cited as the reason for 18 plan failures (see Figure 5.2) and was a contributing reason to even more. Other frequently cited reasons were lack of prerequisite work (14), availability or quality of design information (8), and submittals (6).

Removing rain as a reason, weekly PPC would have been as shown in Figure 5.3, with a mean PPC for the research period of 71% (149 of 211 assignments completed), which compared favorably to work flow reliability achieved through previous application of the Last Planner system to projects which were not subcontracted.[21]

Figure 5.1



CCSR-Weekly PPC

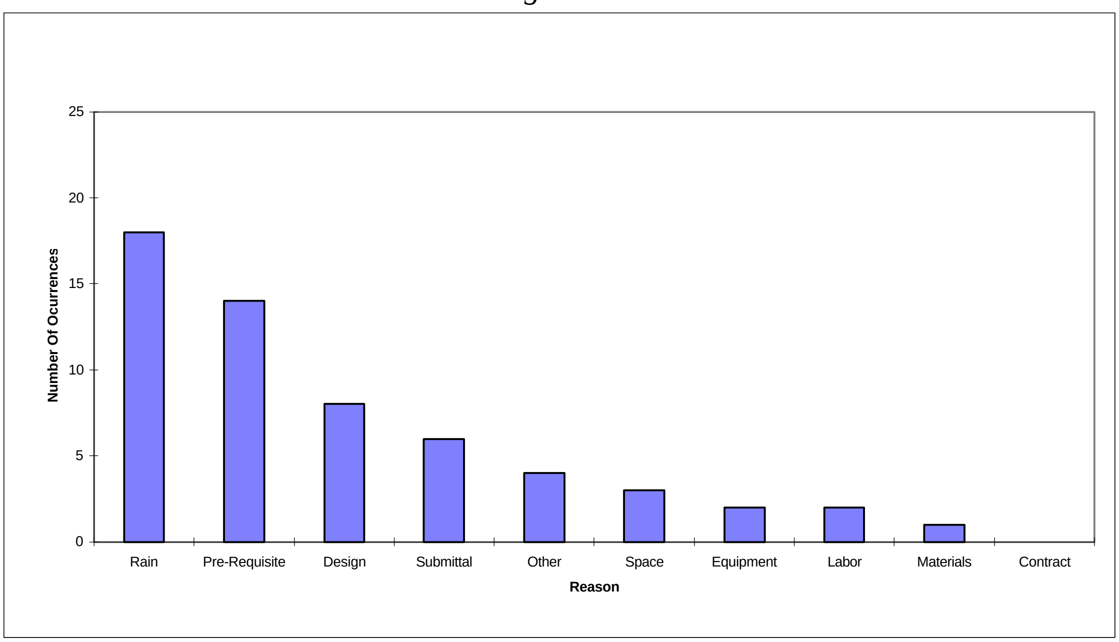
[21] Ballard et al., 1996; Ballard and Howell, 1997

Table 5.3

Week	**12/24/97**	**12/31/97**	**1/6/98**	**1/14/98**	**1/18/98**	**1/25/98**	**2/3/98**	**2/10/98**	**2/17/98**	**2/24/98**	**3/3/98**	
PPC	56%	86%	57%	67%	73%	75%	50%	53%	74%	44%	70%	
Tasks Completed	5	6	8	10	11	18	7	10	23	19	14	
Tasks Planned	9	7	14	15	15	24	14	19	31	43	20	
Rain			1		1	3	6	2	2	1	2	18
Pre-Requisite			2	2	1			7	2			14
Design			1			1			4	2		8
Submittal				2	2	2						6
Other		1					1			1	1	4
Space										1	2	3
Equipment			2									2
Labor										1	1	2
Materials				1								1
Contract												0

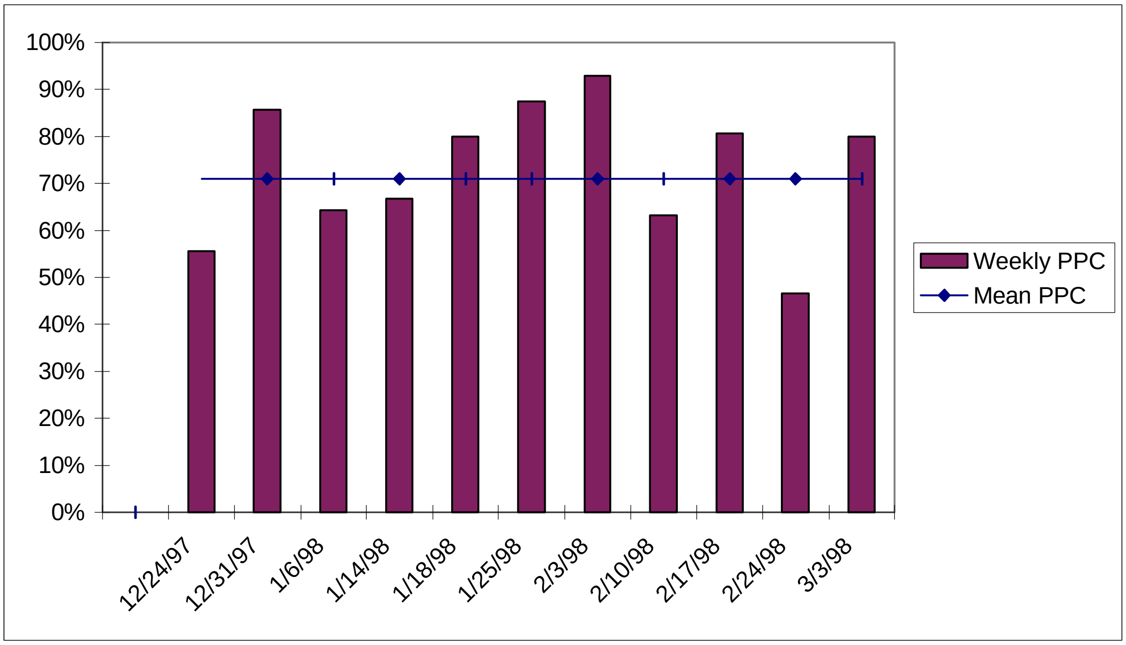
CCSR-PPC and Reasons Data

Figure 5.2



CCSR-Reasons for Noncompletion

Figure 5.3



CCSR-PPC without rain

As shown in Table 5.4, reasons for plan failure were categorized as either an Execution Failure or a Plan Failure[22]. Of the 57 total failures[23], 28 were determined to have resulted from some defect in planning, while 29 were attributed to some defect in execution. The 18 failures caused by rain were categorized as execution failures. Disregarding rain, Plan Failures would have amounted to 28 of 38, or 74%, further evidence that to a substantial degree, our fate is in our own hands as regards planning and work flow. In even extreme weather conditions, fully half of noncompletions resulted from poor planning.

[22] This distinction was introduced into the Last Planner system in Ballard (1994).

[23] Note the absence of detailed information for failures in the week of 12/24/97. Their inclusion would add 4 noncompletions to the total.

Table 5.4

Week 12/31

Activity	Reason	Type Of Failure
item 6 - Sump Pit Lid Form	Other: Low Priority	Plan

Week 1/6

Activity	Reason	Type Of Failure
item 3 - Underground Plumbing	Rain	Execution
Item 13 - East Wall Forms	Design: RFI	Execution
Item 32 - Elevator Wall Forms	Pre-Requisite: Not Identified	Plan
Item 43 - 2&3 Line Excavation	Equipment: Backhoe	Execution
Item 44 - A,C & 4 Line Excavation	Equipment: Backhoe	Execution
Item 45 - 2&3 Line Rebar	No Excavation	Plan

Week 1/14

Activity	Reason	Type Of Failure
item 26 - Elevator 1&2 SOG Pour	Floor Drain Submittals	Plan
Item 44 - Elevator Pour Up to Tunnel Level	Shop Drawings	Plan
Item 43 - Form South East Quadrant	Waiting Rebar Fabrication	Plan
Item 29 - Rebar J Line	Waiting On Excavation	Plan
Item 7 - Access Panel	Submittal	Plan

Week 1/18

Activity	Reason	Type Of Failure
210 - Design Change Rebar Submittals	Not Back	Plan
270 - Interior Wall Rebar Submittals	Not Back	Plan
A,C, & 4 Line Excavation	Productivity/Rain	Execution
A,C, & 4 Line Rebar	No Excavation	Plan

Week 1/25

Activity	Reason	Type Of Failure

Excavate Line F and 7 (MidWest)	Rain	Execution
Interior Wall Forms	Rain	Execution
N,Q,L Lines Rebar Installation	Rain	Execution
Reveals Location	Waiting On Architect	Plan
RFI Line 7 (Cupertino)	Answer Incomplete	Plan
Tunnel Piping Submittal	Approval	Plan

Week 2/3

Activity	**Reason**	Type Of Failure
Excavate F Line	Rain	Execution
Backfill Sump pit	Rain	Execution
Template Footings A and 4 Line	Rain	Execution
Electrical Conduit Elevator 5	Rain	Execution
Small and Large Walls Single Form	Rain	Execution
Wall Double up @ Tunnel Lobby	Waiting For Inspection	Plan
Backfill N-E/S-E Quad.	Rain	Execution

Week 2/10

Activity	**Reason**	Type Of Failure
Plumbing between lines J & M	Rain	Execution
Plumbing Line 6.5	Rain	Execution
Small Interior Walls Form	Eleveator Jack Drilling / Rain	Execution
Small Interior Walls Double Up	Eleveator Jack Drilling / Rain	Execution
Large Interior Walls Form	Eleveator Jack Drilling / Rain	Execution
Large Interior Walls Double Up	Eleveator Jack Drilling / Rain	Execution
Small Wall Rebar	Eleveator Jack Drilling / Rain	Execution
Line L wall Rebar	Eleveator Jack Drilling / Rain	Execution
E & G Line Rebar from 2 to 5	Eleveator Jack Drilling / Rain	Execution

Week 2/17

Activity	Reason	Type Of Failure
Elevator Wal Backfill	Rain	Execution
Line J Excavation	Backfill Plumbing/Rain/Mud	Execution
Line 6.5 Excavation	After 6 & 7 Line Concrete	Plan
Small Interior Wall Forms	Design Change	Plan
Small Walls Double Up	Design Change	Plan
Small Walls Rebar	Design Change	Plan
Perimeter Wall Line 2 Rebar	Design Change	Plan
Footings 6 & 7 Rebar	Rain	Execution

Week 2/24

Activity	Reason	Type Of Failure
Planter Excavation	Space	Plan
Interior Small Walls	Rebar Change/Permit	Plan
Tunnel lobby SOG	Sequence Change	Plan
Line L Wall	Rebar Change/Permit	Plan
Line J Footing	Rain	Execution
Wall Line 2 From A-D	Man Power	Plan

Week 3/3

Activity	Reason	Type Of Failure
Footings E&G Excavation	Space For Crane	Plan
Line J Concrete	Rain	Execution
Footings 6&7 Concrete	Rain	Execution
Court Yard Planter	Crane Reach	Plan
Small Interior Walls	Man Power	Plan
Pipe Ties In @ Tunne	Waiting On Stanford Info	Plan

CCSR-Reasons for Noncompletion (detailed and categorized)

5.3 Observations

Subcontractors were not selected based on their understanding or willingness to participate in the Last Planner production control system. They were selected based on traditional criteria such as financial soundness and bid price. Subcontractor personnel first learned about the system and the expectations regarding their roles and responsibilities within it after coming to the site. Not surprisingly, some were more capable and enthusiastic about participating than others. Even so, the project superintendent continued to use the Last Planner system and reported that eventually all foremen were participating and that they began to hold each other accountable for keeping their weekly work plan commitments. Nonetheless, it would have been preferable both to incorporate participation in the production control system in the selection criteria and subcontracts, and also to have devoted more time and effort to education and training.

Shortly after introducing the system, it became apparent that more active involvement of others besides the site foremen was needed. Subcontractor project managers were invited to attend the weekly meetings and were better able to understand what was going on, and specifically better able to provide status information regarding constraints such as submittals, design issues, fabrication, and deliveries. There was also efforts made to involve the architect and design engineers on the project. Unfortunately, those efforts failed, in part because of the stage of design completion and the fact that the production architect/engineer was on a lump sum contract and concerned lest they run out of money before they ran out of work.

Analysis of constraints was a key element introduced into the Last Planner system on CCSR. Efforts to collect constraints information from subcontractors prior to the coordination meeting were mostly unsuccessful, perhaps in large part because there is no tradition in our industry for such activities. Consequently, much of meeting time was dedicated to data collection rather than planning and problem solving.

5.4 Learnings

Learnings for future projects included:

- Incorporate production control requirements into subcontracts.
- Select subcontractors for their ability and willingness to participate in the production control system.
- Involve owner, architect, and engineers in the production control process; preferably from the beginning of design.
- Send to subcontractor project managers by email or fax each week constraint reports with the next 5-6 weeks scheduled activities listed and ask them to status their activities and report back. Make sure this happens so meeting time can be used for planning and problem solving as opposed to data collection.
- Use team planning techniques to produce schedules for each phase of work, with participation by foremen, superintendents, and designers.
- Incorporate reasons identification, analysis, and corrective action into weekly coordinating meetings. Otherwise, there is a danger that incompletions become accepted as unavoidable.

CHAPTER SIX: CASE 2-NEXT STAGE PROJECT

6.1 Description of the Project and Last Planner Implementation

Next Stage Development was created to design, build, and operate a series of 7,000 seat enclosed amphitheaters in various U.S. cities, accommodating Broadway shows and musical entertainment with amplified sound. Its first project was the Texas Showplace, located in Dallas, Texas. Architect, design consultants, engineering firms, fabricators, and construction contractors were selected based on qualifications and willingness to participate in the project. The intent was to create an All-Star team by selecting the very best.

The general contractor and equity participant in Next Stage Development is Linbeck Construction, a founding member of the Lean Construction Institute, which was cofounded by the author and Greg Howell in August, 1997. Next Stage's management chose to implement elements of "lean thinking" in the design and construction of its facilities, specifically including the Last Planner method of production control. A Kickoff Meeting was held for the production team May 19-21, 1998 in Houston, Texas and co-facilitated by the author. Key outcomes of the meeting were 1) forming the fifty plus individuals and multiple companies into a team, and 2) collectively producing a "value stream" (Womack and Jones' [1996] term for the flow diagram of a production process that produces value for the stakeholders in the process). This author's report on the Kickoff Meeting is included in Appendix A.

In the Kickoff Meeting, the participants were divided into a number of different teams, corresponding roughly to the facility systems: Site/Civil, Structural, Enclosure/ Architectural, Mechanical/Electrical/Plumbing/Fire Protection, Theatrical/Interiors, and

Project Support. These teams remained intact as the administrative units for production of the design.

After the Kickoff Meeting, the design process continued, initially with a target completion date of 11/15/99. However, after roughly the middle of August, 1998, delays in arranging equity financing and performance commitments caused the construction start and end date to slip ever further out, until the project was finally suspended..

The design process was managed primarily through biweekly teleconference (Appendix B). Tasks needing completion within the next two week period were logged as Action Items (Appendix C) , with responsibility and due date assigned. Tasks needing completion beyond the next two week period were logged as Issues (Appendix D). Design decisions were recorded in a Design Decisions Log (Appendix E). When action items were not completed as scheduled, reasons were assigned from a standard list (Table 6.1) and a new due date was provided.

Table 6.1

1. Lack of decision
2. Lack of prerequisites
3. Lack of resources
4. Priority change
5. Insufficient time
6. Late start
7. Conflicting demands
8. Acts of God or the Devil
9. Project changes
10. Other

Next Stage-Reasons for Noncompletion

6.2 Data

6.2.1 PPC AND REASONS

The percentage of action items completed was tracked and published biweekly.

Table 6.2

PPC - NextStage™ Texas ShowPlace Planning Percent Complete for Preconstruction Meetings

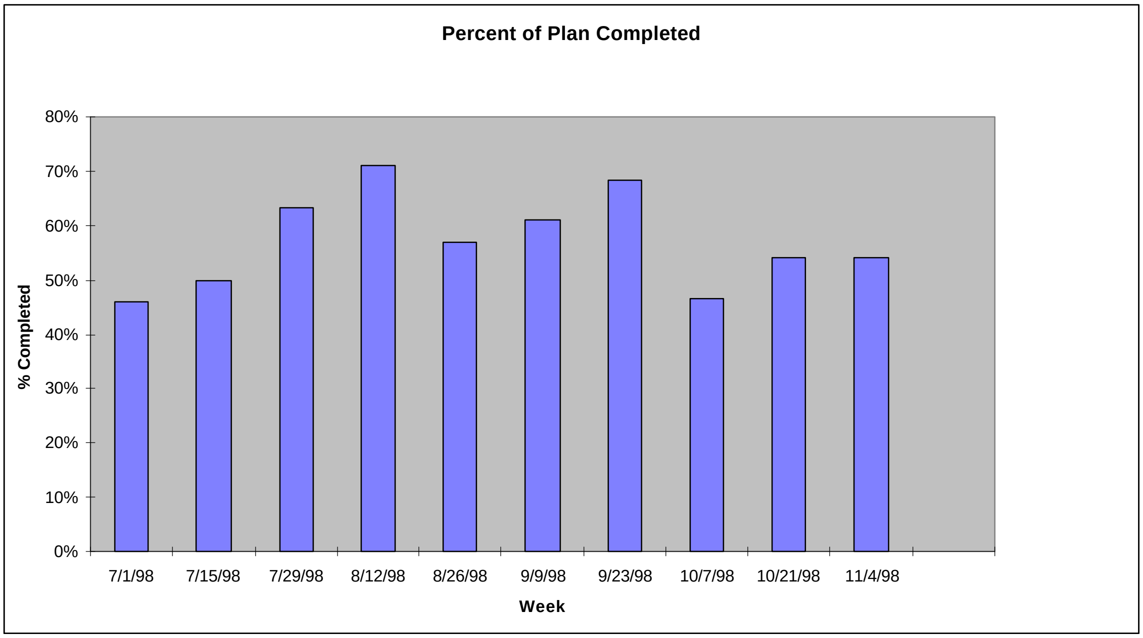
Week	7/1/98	7/15/98	7/29/98	8/12/98	8/26/98	9/9/98	9/23/98	10/7/98	10/21/98	11/4/98
4 week moving ave.				57%	60%	63%	64%	58%	57%	55%
PPC	46%	50%	63%	71%	57%	61%	68%	47%	54%	54%
Tasks Completed	28	33	48	37	29	36	26	20	26	20
Tasks Planned	61	66	76	52	51	59	38	43	48	37

Next Stage-PPC Data

The number of tasks or action items completed was divided by the number planned each two week period and a percentage calculated. For example, In the two week period beginning 11/4/98, 37 action items were assigned, of which 20 were completed, which amounts to 54%. In addition, a four week moving average was calculated in order to smooth the data and hopefully reveal trends. Through 11/4/98, the four week moving average was 55%, calculated by averaging the previous four weeks data.

The columns in Figure 6.1 represent the aggregate average completion percentage for all teams for each two week planning periods. PPC rose from an initial measurement of 46% to above 70% in the 4th two week planning period. Subsequently, perhaps connected with the end date slipping out, PPC rose and fell in a generally downward trend, winding up around 55%.

Figure 6.1



Next Stage PPC Data

There was considerable variation between teams. Through 9/9/98, PPC of the various teams was as follows:

Site/Civil	78%
Structural	35%
Enclosure/Architectural	62%
Mechanical/Electrical/Plumbing/Fire Protection	55%
Theatrical/Interiors	52%
Project Support	85%

Table 6.3 exhibits the reasons categories used on the project and the frequency of reason by category each week of the data collection period. It is apparent that three categories dominate; i.e., lack of prerequisite work, insufficient time, and conflicting demands, in that order. Unfortunately, such categories reveal little about root causes, so do not facilitate corrective action.

Table 6.3

Reasons/ Date	7/1/98	7/15/98	7/29/98	8/12/98	8/26/98	9/9/98	9/23/98	10/7/98	10/21/98	11/4/98	12/2/98	All Weeks
Decision	1	1	3	1	1		1	3	3	3		17
Prerequisites	7	16	8	2	7	10	3	5	6	4		68
Resources		1	2	0								3
Priority Change	3	4	6	1		1						15
Insufficient Time	5	6	1	6	6	10	8	10	6	4		62
Late start		4	1	1				1		1		8
Conflicting Demands	7	7	3	1	7	2		4	6	5		42
Acts of God			3	0								3
Project Changes				0					1			1
Other				2	1							3

Next Stage-Reasons

6.2.2 OBSERVATIONS (See Appendices A and B for a report on the Kickoff meeting and the author's notes on project teleconferences.)

6.2.3 FEEDBACK FROM PARTICIPANTS

In October, 1998, the Site/Civil team agreed to select five plan failures and analyze them to root causes by asking "Why?" up to five times in succession. Review of Site/Civil's analyses revealed that failure to understand criteria for successful completion of assignments was the most common cause. Generally, failures were caused by not understanding something critically important; City requirements for traffic analysis, applicable codes for drainage, actual soil conditions, who had responsibility for what. Presenting reasons were often quite distant from root causes and frequently the failing party did not control the root cause. This sample also raised significant questions about adherence to quality requirements for assignments. For example, why did Site/Civil accept #1 (were they sure they had the capacity to take on this additional task?) or #2 (why did they think Mechanical would give them the information they needed in time for Civil to do its work?)?

> Failure #1: Failed to transmit site plan package to the general contractor as promised. Reason provided: conflicting demands—"I was overwhelmed during this period." 5 why's revealed that the required time was underestimated for collecting the information needed because the City's requirements for traffic analysis were different and greater than had been assumed.
>
> Failure #2: Failed to revise and submit site drainage for revised commissary roof drainage. Reason provided: prerequisite work. The mechanical contractor originally provided drainage data on pipe sizes, inverts, etc., then discovered that City codes required additional collection points. Civil is waiting on Mechanical to provide data on these additional collection points.
>
> Failure #3: Failed to complete Road "D" plan to support easement and operating items. Reason provided: prerequisite work. The root cause was the same as for #1; i.e., failure to understand City requirements for traffic analysis.
>
> Failure #4: Failed to make an engineering determination from 3 alternative pavement designs provided. Reason provided: prerequisite work and insufficient time. "This item was not anticipated. Why was it not anticipated? The City refused to accept our pavement design. Why did they refuse to accept our

pavement design? Soil conditions were different from past projects. The lack of prerequisite design work referred to the soil borings in the borrow site. We also are investigating other sources for dirt. Why was time insufficient? We neglected to plan for the time required to mobilize soils testing." The root cause was assuming soil conditions would be the same. A process flow diagram might have revealed the significance of that assumption.

Failure #5: Failed to determine/coordinate location of easements after final design by Texas Utilities. Reason provided: prerequisite work. "Prerequisite design work involved the determination of routing and service options. There was confusion over who was responsible. There were delays on the part of TU Electric due to the absence of key people." Failure to specify who was to do what prevented requesting a specific commitment from TU Electric. If TU Electric refused to make that commitment, Civil could have refused to accept its action item until receipt of their input. If TU Electric had committed, Civil might have been informed when key people were absent.

Low PPC was attributed by some members of the management team to the lack of a construction start date, and the consequent use by suppliers of resources on more urgent projects. The high percentage of plan failures due to conflicting demands appears to be supportive of this claim. However, this reasons analysis exercise and observation of teleconferences suggests that contributing causes were failure to apply quality criteria to assignments and failure to learn from plan failures through analysis and action on reasons.

6.3 The Nature of the Design Process and Implications for Process Control

'Making' has the job of conforming to requirements. Design produces those requirements. If there were complete predictability of design's output, design would generate no value. Consequently, variability plays a different role in design as opposed to construction (Reinertsen, 1997). This raises the question of the type of control appropriate to generative processes like design.

Let us first consider more closely the nature of the design process. Consider the task of producing a piping isometric drawing versus the task of doing a piping layout for a given area. In order to do the layout, the designer must know where other objects are located in the space. She must know locations, dimensions, material compositions, and operating characteristics of end-points. Some of these constraints and conditions of her problem will not change. Some may well change in response to her difficulty achieving a satisfactory solution. Consequently, the final piping layout will emerge from a process of negotiation and adjustment, which cannot be determined in advance.

An example from the Next Stage case illustrates the point. The design team was faced with selecting the theater seats, which might appear at first glance to be a fairly simple problem of applying criteria derivative from the general level of 'quality' desired in the facility balanced against the purchase price of the seats. In fact, the criteria are far from straightforward or simple. Seats can either be mounted on the floor or riser-mounted, the choice between them being interdependent with the structural pads for the seats, which in turn constrains choices regarding the return air plenum, which can either go through the floor or risers. That choice in turn impacts cleaning time and cost: how quickly can they set up for the next show? As it happens, chairs come with different types of upholstery, which can change the amount and type of smoke to be removed.

Components such as chairs may not be offered in all varieties; e.g., although we might prefer a riser-mounted chair, such chairs only come with a certain type of upholstery that would overload current plans for smoke removal. Everything's connected to everything. We are designing one whole, so parts have the logic of part to whole, potentially conflicting properties, etc. Product design decisions can impact the entire range of 'ilties': buildability, operability, maintainability, etc., etc. In this case, delay in selecting chairs delayed final determination of structural geometry, which in turn delayed completion of the 3D model of the structure.

Overly 'rationalistic' models of problem solving processes are inappropriate for the design process, which rather oscillates between criteria and alternatives, as in a good conversation from which everyone learns (See Conklin and Weil's "Wicked Problems" for another presentation of this idea.). In their *Soft Systems Methodology*, Checkland and Scholes offer the same critique of 'hard' systems thinking as applied to action research; i.e., such thinking failed because it assumed that objectives were defined and the task was simply to determine how to achieve those objectives. Rather than conceiving the project process to consist of determining design criteria then applying those criteria in the production of the design, design should be conceived as a value generating process dedicated to the progressive determination of both ends and means.

Specialization is essential for successful design. No one can understand in detail all the different types of criteria, constraints, and alternatives that might be considered. However, specialists tend toward suboptimization because they become advocates for what they understand to be important, often without sufficient understanding of what else is important[24]. Specialists are often advocates for the priority of specific criteria!

Given this value generating nature of design, controls based on the model of after-the-fact detection of negative variances inevitably focus entirely on controlling time and cost, leaving design quality as the dependent variable (p.199, Reinertsen, 1997). What is needed is a production control system that explodes tasks near in time to their performance, one that counteracts the tendency to suboptimization by explicitly focusing common attention on design criteria, one that facilitates value generation and information flow among specialists; i.e., the Last Planner system.

6.4 Evaluation of Last Planner Implementation

Four Next Stage project managers evaluated implementation and effectiveness of the Last Planner system in response to a short survey produced by the author. The four rated Last Planner effectiveness relative to traditional forms of project control 5, 5, 6, and 7 on a scale of 1 to 7, which is equivalent to saying that Last Planner was 44% more effective than traditional practice. However, examination of actual practice on the project suggests tremendous opportunity for further improvement.

Plus: -attempted to select only assignments needed to release other work

-measured and communicated PPC and reasons

[24] See Lloyd, et al., 1997 for the tendency to see one's task in terms of one's 'product' rather than in terms of participating in an iterative, interactive, evolving process.

Minus: -minimal preparation of participants

-no work flow control and make ready process

-poor definition of assignments

-no action on reasons

Each action item was determined completed or incomplete, and reasons were selected from the list of categories. However, no analysis of reasons was done, either during or between teleconferences. There was also no apparent attempt to act on the reasons that were identified. Work selection was tested against the 'pull' requirement by asking why it was needed to be done now, but rarely were assignments rejected for unsoundness or size. Frequently, it appeared that assignments were accepted with the implicit commitment to do one's best rather than an explicit commitment to complete based on knowledge of the execution process, understanding of relevant criteria, identification of needed informational inputs, and allocation of necessary resources. Assignments were not systematically exploded into an operations level of detail and, consequently, the interdependence of assignments was often not understood.

In summary, Next Stage did not fully change its production control system from the traditional, and either did not implement or did not implement completely the elements of the Last Planner system; i.e., work flow control, production unit control, and a learning process. Nonetheless, the Next Stage experience was valuable for its contributions to learning and further development of the Last Planner System. Much has been learned and developed since the Next Stage case. Opportunities and needs for the future are well summarized by Ed Beck, Linbeck project manager, in the following response to the author's survey question: *What improvements in LPS (Last Planner System) objectives, procedures, or implementation do you suggest for future projects?*

- Client buy-in at the user level
- Complete orientation of all participants
- A simpler value stream
- A more systematic format
- A better list of reasons to categorize planning failures
- Utilization of the 5 why's
- Utilization of the 6 week lookahead
- A more expeditious way to meet and create a weekly plan
- Periodic revisiting of the value stream
- Publishing graphs and reasons and answers to questions to all
- A tune-up meeting at strategic times along the course of the project
- Periodic assessment comparing what is happening versus what normally happens.

6.5 Learnings

The Next Stage case study reinforced the need to improve plan reliability in design processes and also suggested improvements to the production control system required to achieve better plan reliability.

-make sure project management understands the production control system and its objectives

-provide additional training to participants

-include ‘puller’ on action item log

-explode scheduled activities using the Activity Definition Model; i.e., specify the process to be used to complete an assignment, the directives or criteria to which it must conform, the prerequisite work needed from others, and the resources necessary to do the work.

-establish a lookahead window with screening criteria for advancement

-track the status of assignments as they move through the lookahead window

-adopt a sizing criterion for assignments that consistently demands less output from production units than their estimated capacity to accommodate variability in capacity. (This seems especially important for design. Other studies suggest that routinely 20% of capacity is used to do needed but previously undefined work each week.)

-improve the categorization of reasons and reasons analysis to facilitate implementation of the learning process, which consists of: analyze reasons to actionable causes, assign or take corrective action, and record results.

CHAPTER SEVEN: CASE THREE-PACIFIC CONTRACTING

7.1 Project Description and Last Planner Implementation

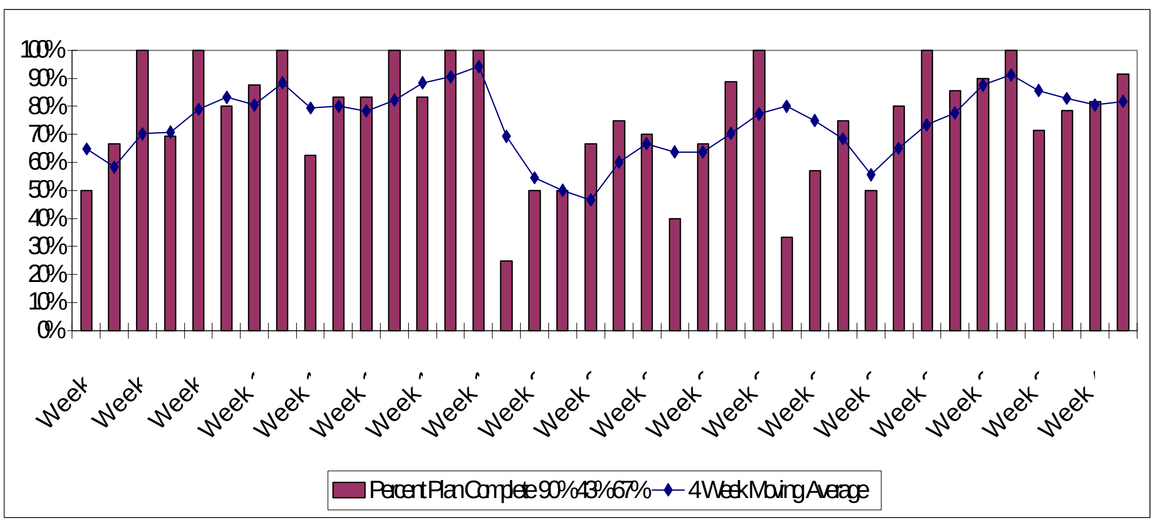
Pacific Contracting is a speciality contractor primarily involved in design and installation of building envelopes; i.e., cladding and roofing systems. The author began working with the company in 1995 as a consultant. Subsequently, Pacific Contracting became a charter member of the Lean Construction Institute and its President, Todd Zabelle, became an LCI partner.

Implementation of the Last Planner system by a speciality contractor is important for several reasons. First of all, specialists work for many general contractors, not all of whom may endorse the Last Planner principles and objectives. Secondly, the specialist has a different role in the production system than does a general contractor or construction manager. The latter's role is primarily to coordinate production, but the production itself is done by specialists, even if they are directly employed by the general contractor. Drawing on a manufacturing analogy, the speciality contractor is like a job shop, while the coordinator is like an assembler. Many of the functions of the Last Planner system, such as matching load to capacity, fall more particularly on the specialist, whether design or construction, than on the coordinator of design or construction processes.

7.2 PPC and Reasons

Pacific Contracting, using the latest tools and techniques developed by the author, participated in the effort to discover how to improve PPC to and above the 90% level, an LCI research project. The data collection period extended for 41 weeks, ending in mid-October, 1999[25]. As can be seen from Figure 7.1, there appears to have been a period of improvement through Week 19, then a decline followed by another upward trend through Week 28, followed by a brief period of decline, with finally another upward trend through the period of data collection.

Figure 7.1



Pacific Contracting-PPC

[25] The LCI research on improving PPC continued beyond the data collection period reported in this dissertation.

A possible explanation for the decline is that a very small number of assignments were actually made ready in time to be placed on weekly work plans, so that a single noncompletion registered as a relatively large percentage of failures. As shown in Table 7.1, from Week 17 through Week 23, no more than 4 tasks were assigned on weekly work plans. From Week 19 through 23, at least one weekly assignment was not completed, limiting PPC to a maximum of 75%. This likely impact of lookahead planning on PPC adds impetus to the need for future development of metrics specifically for the lookahead process and its improvement.

Table 7.1

Week	1	2	3	4	5	6	7	8
Percent Plan Complete	90%	43%	67%	50%	67%	100%	69%	100%
4 Week Moving Average	0%	0%	0%	65%	58%	70%	71%	79%
Activities Scheduled	10	7	9	8	12	8	13	5
Activities Complete	9	3	6	4	8	8	9	5
Total Incompletions	1	4	3	4	4	0	4	0
Activities Scheduled	10	7	9	8	12	8	13	5
Client	0	0	0	0	0	0	0	0
Engineering	0	0	0	0	1	0	0	0
Materials	0	0	0	1	0	0	1	0
Equipment	0	0	0	0	0	0	0	0
Craft	0	0	0	0	0	0	0	0
Pre-Requisite	0	1	1	0	0	0	0	0
Subcontractor	0	2	1	0	0	0	2	0
Plan	1	1	1	3	3	0	1	0
Weather	0	0	0	0	0	0	0	0

Week	9	10	11	12	13	14	15	16
Percent Plan Complete	80%	88%	100%	63%	83%	83%	100%	83%
4 Week Moving Average	83%	81%	88%	79%	80%	78%	82%	88%
Activities Scheduled	10	8	3	8	6	6	8	6
Activities Complete	8	7	3	5	5	5	8	5
Total Incompletions	2	1	0	3	1	1	0	1
Activities Scheduled	0	0	0	0	0	0	8	6
Client	0	0	0	0	0	0	0	0
Engineering	0	0	0	1	0	0	0	0
Materials	0	0	0	0	0	0	0	0
Equipment	0	0	0	0	1	0	0	0
Craft	0	0	0	0	0	1	0	0
Pre-Requisite	0	0	0	0	0	0	0	0
Subcontractor	1	0	0	1	0	0	0	0
Plan	1	1	0	1	0	0	0	0
Weather	1	1	0	1	0	0	0	1

Week	17	18	19	*20*	21	22	23	24
Percent Plan Complete	100%	100%	25%	50%	50%	67%	75%	70%
4 Week Moving Average	90%	94%	69%	55%	50%	47%	60%	67%
Activities Scheduled	1	2	4	4	4	3	4	10
Activities Complete	1	2	1	2	2	2	3	7
Total Incompletions	0	0	3	2	2	1	1	3
Activities Scheduled	1	2	4	4	4	3	4	10
Client	0	0	0	0	0	0	1	1
Engineering	0	0	1	0	0	0	0	0
Materials	0	0	0	0	0	0	0	0
Equipment	0	0	0	0	0	0	0	0
Craft	0	0	0	0	2	0	0	0
Pre-Requisite	0	0	2	0	0	0	0	0
Subcontractor	0	0	0	1	0	0	0	2
Plan	0	0	0	1	0	1	0	0
Weather	0	0	0	0	0	0	0	0

Week	25	26	27	28	29	30	31	32
Percent Plan Complete	40%	67%	89%	100%	33%	57%	75%	50%
4 Week Moving Average	64%	64%	70%	77%	80%	75%	68%	56%
Activities Scheduled	5	3	9	5	3	7	4	4
Activities Complete	2	2	8	5	1	4	3	2
Total Incompletions	3	1	1	0	2	3	1	2
Activities Scheduled	5	3	9	5	3	7	4	4
Client	1	0	0	0	0	1	1	0
Engineering	2	0	0	0	0	0	0	1
Materials	0	0	0	0	1	1	0	0
Equipment	0	0	0	0	0	0	0	0
Craft	0	0	0	0	0	0	0	0
Pre-Requisite	0	0	0	0	0	0	0	1
Subcontractor	0	0	0	0	1	0	0	0
Plan	0	1	1	0	0	1	0	0
Weather	0	0	0	0	0	0	0	0

Week	33	34	35	36	37	38	39	40	41
Percent Plan Compl	80%	100%	86%	90%	100%	71%	79%	82%	92%
4 Week Moving Ave	65%	73%	78%	88%	91%	86%	83%	81%	82%
Activities Schedule	5	2	7	10	4	7	14	11	12
Activities Complete	4	2	6	9	4	5	11	9	11
Total Incompletions	1	0	1	1	0	2	3	2	1
Activities Schedule	5	2	7	10	4	7	14	11	12
Client	0	0	0	1	0	0	0	0	0
Engineering	0	0	0	0	0	0	0	0	0
Materials	0	0	0	0	0	0	0	0	0
Equipment	0	0	0	0	0	0	0	0	0
Craft	0	0	1	0	0	2	2	0	0
Pre-Requisite	0	0	0	0	0	0	0	0	1
Subcontractor	0	0	0	0	0	0	0	0	0
Plan	1	0	0	0	0	0	1	2	0
Weather	0	0	0	0	0	0	0	0	0

Pacific Contracting-PPC Data and Reasons

Pacific Contracting categorized reasons for noncompletion of weekly assignments in terms of Client, Engineering, Materials, Equipment, Craft, Prerequisite Work, Subcontractor, Plan, or Weather. Bret Zabelle, Operations Manager for Pacific Contracting, provided the following comments regarding their reasons categories:

> "As I started to write our definition of engineering as a reason, I had a moment of clarity. Engineering cannot be a reason. You either have the engineering for a task complete or you don't. If you don't have the engineering complete, the task should not be scheduled on a work plan. The only instances I can think of for engineering is miscalculation of quantities, structural collapse or failure.

> "Craft:When all the resources are available to perform a task on the WWP (weekly work plan) and the craft workers do something different. Also refers to craft absenteeism.

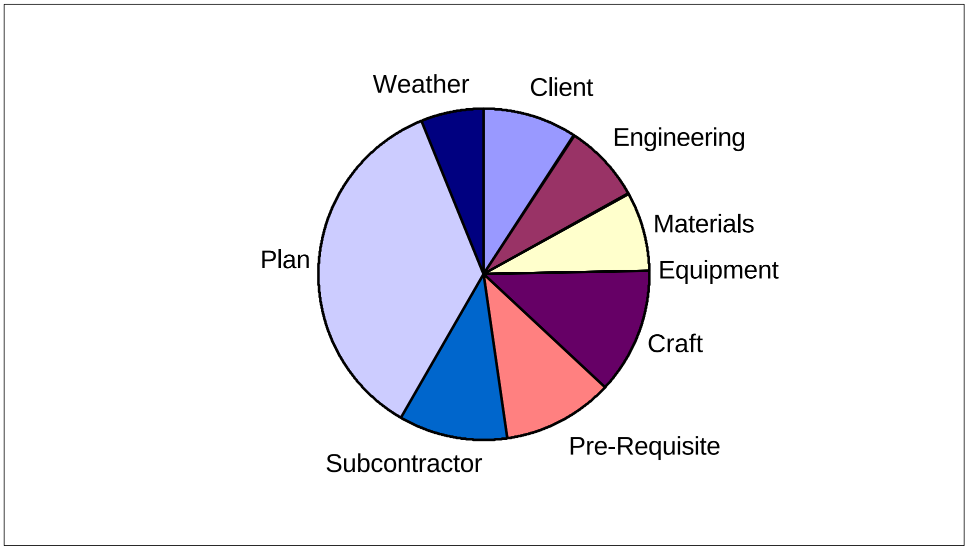
> "Subcontractor: This is similar to engineering as a reason. If we have a subcontractor who did not complete prerequisite work in front of us, we should not put our activity on the WWP until it is available. Also refers to fabricators. They promise components will be fabricated by a certain date and fail.

> "Plan: Planning failures occur when we do stupid things like schedule activities if the engineering is not complete, materials, tools and workers are not available, our own subcontractors or other contractors have not completed prerequisite activities. Sometimes we schedule tasks that are more complex than we thought."

Considering reasons for failures to complete weekly assignments, as shown in Table 7.1 and also graphically in Figure 7.2, much the most common reason was "Plan", Pacific Contracting's own disregard of assignment quality criteria or inability to understand how the planned work was to be done, and to anticipate all the steps and resources necessary. The next most frequent reason was errors of some sort in execution of assignments by Pacific Contracting's craft supervisors and workers.

Altogether, the vast majority of weekly work plan failures were well within the control of Pacific Contracting. However, it should be remembered that matters might be just the opposite as regards the lookahead process which makes ready assignments for selection in weekly work plans. Again, we are reminded of the importance of measuring and analyzing lookahead process performance.

Figure 7.2



Pacific Contracting-Reasons

7.3 Observations

During the period of data collection, Pacific Contracting did not work with a single general contractor that embraced the Last Planner system. Specialists appear to have tremendous difficulty achieving high levels of PPC when not working on 'last planner' projects. The consequent lack of resource utilization is a waste the recovery of which could contribute to faster or more projects. On the other side of the matter, speciality contractor efforts to avoid that waste seem inevitably to decrease both plan reliability and progress of projects as seen from the perspective of project coordinators.

Once work is available to speciality contractors, they appear-based on this one instance-to be able to achieve a relatively high level of plan reliability, limited mostly by their own ability to plan and execute.

7.4 Learnings

For speciality contractors to increase plan reliability to the 90% level and above requires that the coordinators of the projects on which they work embrace the Last Planner system's objectives and especially the lookahead process, which is dedicated to making tasks ready for assignment and to balancing load and capacity. For their part, speciality contractors must adhere to the discipline of Last Planner rules and perhaps also use the technique of first run studies[26] more consistently and well.

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[26] First run studies are extensive planning of upcoming operations by a cross functional team including representatives of those who are to do the first operation, followed by methodical study, redesign of the operation, and retrial until a standard is established to meet or beat for execution of that operation. First run studies follow the Shewhart Plan-Do-Check-Act cycle, made popular by W. Edwards Deming.

CHAPTER EIGHT: CASE FOUR-OLD CHEMISTRY BUILDING RENOVATION PROJECT

8.1 Project Description and Last Planner Implementation

Linbeck Construction, a founding member of the Lean Construction Institute, was the general contractor for Rice University's Old Chemistry Building Renovation Project in Houston, Texas. Linbeck brought John Pasch, Rice's facilities manager, to the Neenan Company's annual winter conference in 1998. At that conference, James Womack spoke on the need and opportunity to extend lean production (manufacturing) concepts and techniques to the construction industry and Greg Howell[27] shared the Lean Construction Institute's vision of that application. John was sufficiently impressed that he allowed Linbeck to negotiate with its primary subcontractors rather than competitively bid them as had been the University's practice. At this point, a substantial building program stood in the offing and Linbeck was one of three contractors competing for the lion's share.

Kathy Jones, Linbeck's project manager, had the author conduct several educational and training sessions with project personnel, including the architect. Unfortunately, the architect refused to participate in the Last Planner system. However, the subcontractors became totally committed and enthusiastic about the planning process during the course of the job, as did Rice University's personnel. The project was completed to a very aggressive schedule to the satisfaction of users and within the budget. Rice University was so well pleased with the performance that Linbeck won its Fondren Library Project, and is well situated to do roughly half a billion dollars worth of work in the Rice Program over the next several years.

8.2 PPC and Reasons

The author facilitated team scheduling exercises that produced an overall project schedule, then a more detailed schedule for the initial phase of work and the design development needed to support it. That phase schedule became the driver for weekly work planning, the results of which are shown in Figure 8.1.

Over a period of approximately eleven weeks, PPC rose to a level of 85% or so, then stabilized at that level for the duration of the project. This was an unprecedented accomplishment at the time, and resulted from the dedication of the owner, general contractor, and subcontractor personnel to the Last Planner System and its goal of plan reliability. Kathy Jones reinforced the Last Planner principles by fining those who used the expression 'I hope' or 'hopefully' in connection with a commitment to do work. (The fine was a six pack of beer to be collected at the project-ending celebration.) The project manager for one subcontractor volunteered at an LCI research workshop that "It's fun to go to work now!"

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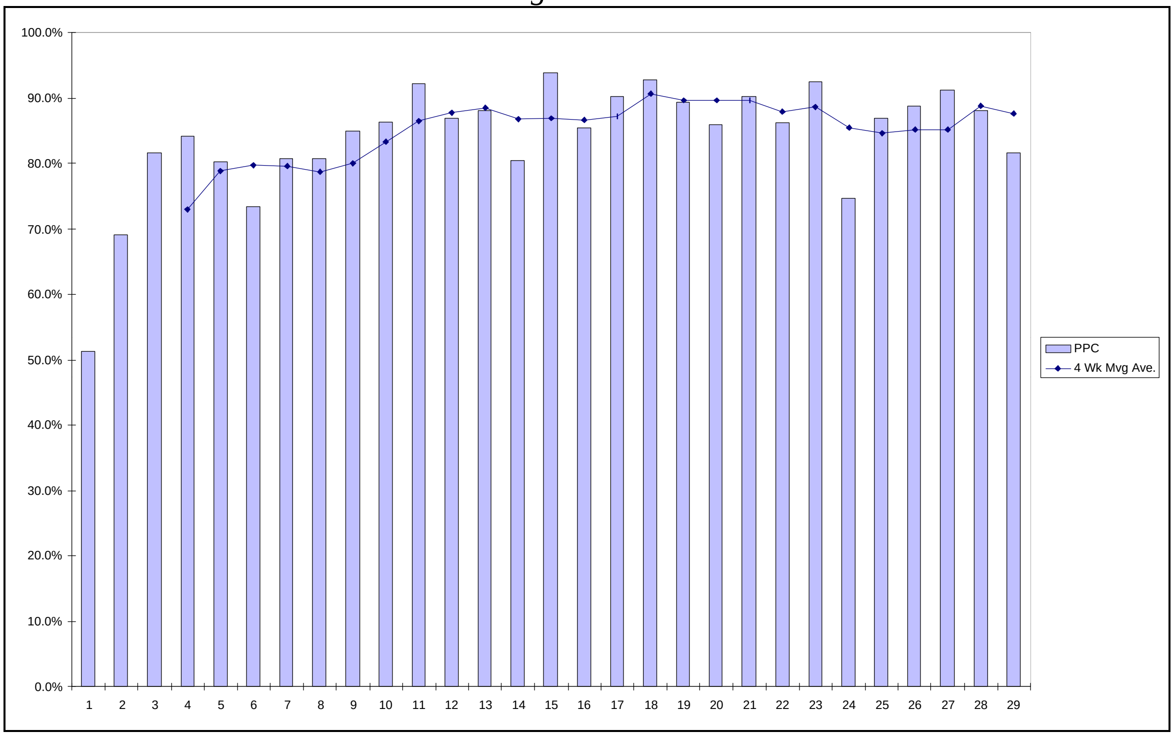
[27] Co-founder with the author of the Lean Construction Institute in August, 1997.

Figure 8.1



Old Chemistry Building-PPC

Table 8.1

Date	**1/25/99**	**2/1/99**	**2/8/99**	**2/15/99**	**2/22/99**	**2/29/99**	**3/8/99**	**3/15/99**	**3/22/99**	**3/29/99**	**4/5/99**	**4/12/99**	**4/19/99**	**4/26/99**
Tasks Completed	20	38	40	48	49	44	46	46	56	57	71	66	66	66
Tasks Assigned	39	55	49	57	61	60	57	57	66	66	77	76	75	82

Date	**5/3/99**	**5/10/99**	**5/17/99**	**5/24/99**	**6/1/99**	**6/7/99**	**6/14/99**	**6/21/99**	**6/28/99**	**7/6/99**	**7/12/99**	**7/19/99**	**7/26/99**
Tasks Completed	60	53	65	64	50	55	65	69	62	62	66	63	73
Tasks Assigned	64	62	72	69	56	64	72	80	67	83	76	71	80

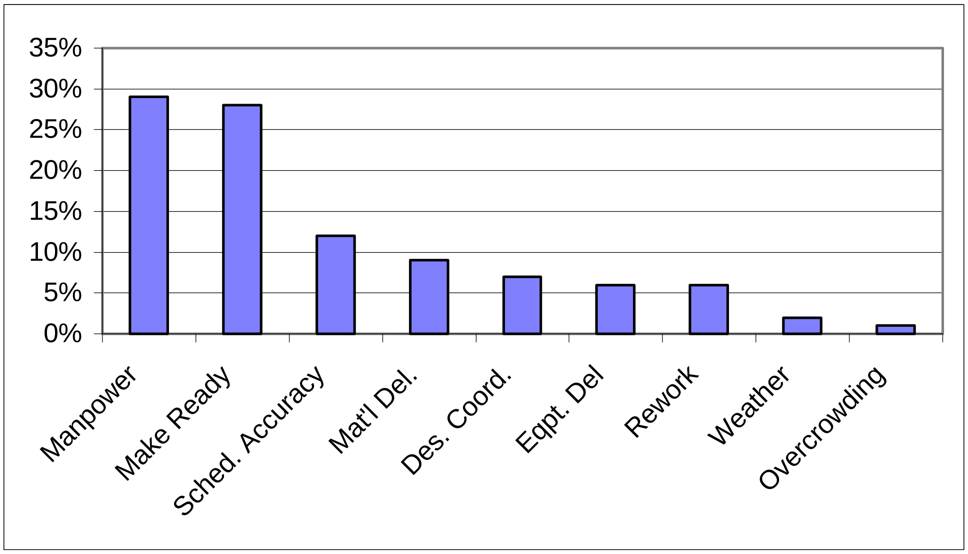
Date	**8/2/99**	**8/9/99**
Tasks Completed	59	53
Tasks Assigned	67	65

Old Chemistry Building-PPC Data

Of the relatively few failures to complete weekly assignments, most were caused by lack of manpower or failure to complete prerequisite work ("make ready"). As this occurred during a building boom in the Houston area, the low frequency of manpower problems is a testament to the subcontractors' dedication to the project.

The remaining reasons categories were Schedule Accuracy (the assignment shouldn't have been made), Material Deliveries, Design Coordination, Equipment (part of the building, not construction equipment), Rework, Weather, and Overcrowding.

Figure 8.2



Old Chemistry Building-Reasons for Noncompletions

8.3 Observations

Lack of participation by the architect was a serious deficiency on the project, perhaps concealed by the high PPC and low incidence of design coordination as a reason for failing to complete weekly work plan assignments. Design problems did impact the job, but that impact would only be evident in schedule changes and in the lookahead process.

Unfortunately, the lookahead process was not fully and formally developed on this project, in part because it was still being defined and its techniques created at the time Old Chemistry was initiated.

Linbeck intends to extend the Last Planner System to the design phase of the Fondren Library Project, and has Rice University's agreement to keep the same subcontractors in place for that project. This commercial alliance among Linbeck and its 'preferred' suppliers is a critical component in the recipe for success.

8.4 Learnings

On the positive side, the Old Chemistry Building Renovation Project demonstrated that PPC could be maintained consistently at a level of 85% through development and nurturing of teamwork and the subsequent team enforcement of norms and rules. The commercial success of the general contractor and its subcontractors indicates the power and impact of increasing plan reliability. Specific techniques that were trialed successfully on this project included team scheduling, specifically team production of detailed phase schedules, resulting from intense negotiation among the speciality contractors themselves, within a schedule framework established by the general contractor.

As for things that might be done better on future projects, implementation of Last Planner in design and involvement of design professionals is certainly number one. Lesser issues, but still important, include the need for a more transparent lookahead process and the need for more explicit learning from analysis and action on reasons for failures.

CHAPTER NINE: CASE FIVE-ZENECA PROJECT

9.1 PROJECT DESCRIPTION AND LAST PLANNER IMPLEMENTATION

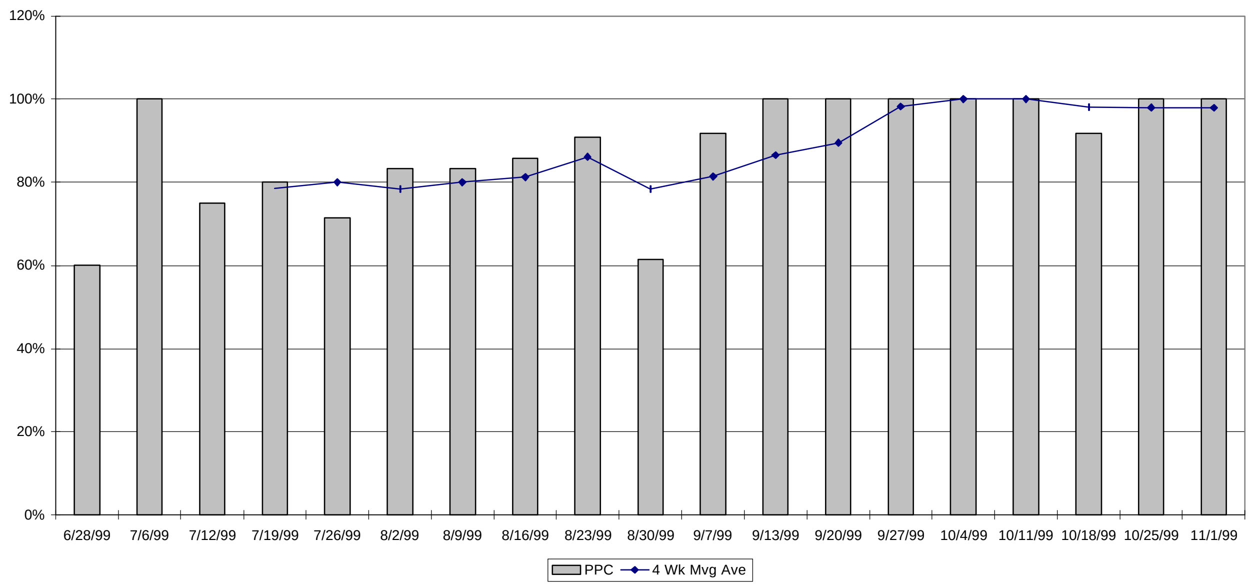
Barnes Construction is a member of the Lean Construction Institute and is embarked on transforming itself into a lean organization. Part of that transformation is to be achieved by implementation and perfection of the Last Planner system of production control. Implementation of the Last Planner system began with classroom training, followed by site visits and coaching, all provided by the author.

Zeneca is a biotechnology company located in Richmond, California near San Francisco. The Zeneca Project reported here is one of a series of seismic retrofits of laboratory and office buildings being performed by Barnes. Of all the cases included in this dissertation, the Barnes case incorporates most of all previous learnings and the latest developments in technique and implementation. One of the critical improvements to be seen is in the methodical analysis and removal of constraints from scheduled tasks.

9.2 PPC AND REASONS

As shown in Figure 9.1, the period of data collection extended from the week of 6/26/99 through the week of 10/11/99. It appears that PPC gradually improved throughout that period until culminating in four consecutive weeks in which PPC measured 100%.

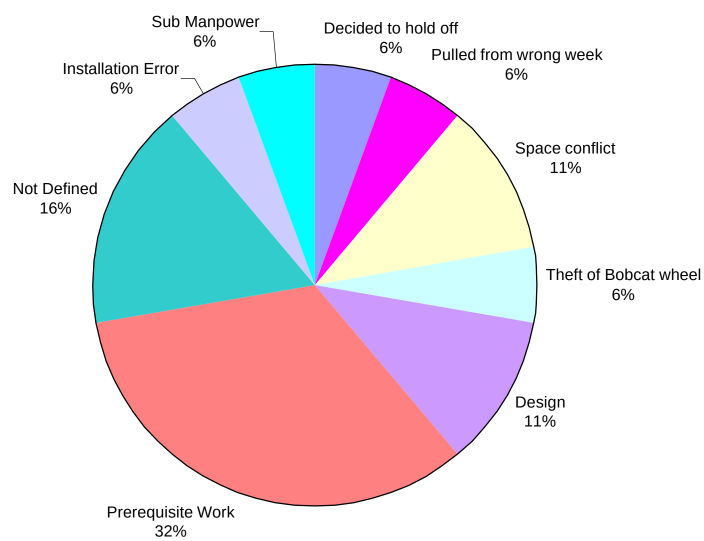
Figure 9.1



Zeneca-PPC

With such a high percentage of weekly assignments completed, there were relatively few

Figure 9.2



Zeneca-Reasons

noncompletions, and so few occasions for identifying reasons for noncompletions. Such as were identified are shown in Figure 9.2.

9.3 Constraint Analysis and Make Ready

The technique of constraints analysis, pioneered on the CCSR Project, became a key tool in Zeneca's success. As originally envisioned, status information regarding constraints was collected each week on all tasks scheduled to start within the next 6 weeks. Notes and action items were added to the constraint analysis form to serve as a reminder to various parties regarding the actions they needed to take to make tasks ready in time to be performed. The primary rule applied to this lookahead process was to only allow tasks to retain their scheduled starts if the planners were confident they could be made ready in time. Otherwise, they were to appeal for help to higher levels of their organizations, then, if make ready actions indeed could not be taken in time, defer the task until it could be made ready.

Following is a statement, by this writer, of the directives governing the Last Planner system installation and execution at Barnes:

Barnes Production Control Requirements

1. Hold weekly subcontractor coordination meetings on each project. Insist subcontractors give input into weekly work plans and lookahead schedules.
2. Select weekly work plan assignments from those that meet quality criteria of definition, soundness, sequence, and size. Issue weekly work plans and expect every superintendent and foreman to have them in their pocket. Use the weekly work plan form and be sure to complete all sections, including make ready needs and workable backlog. When assigned tasks extend beyond one week, specify what work is to be completed within the week.
3. Each week, calculate the percent plan complete (PPC) for the previous week and identify reasons for each assignment that was not completed. Try to get to root

or actionable causes. Don't beat people up for plan failure, but insist that they learn from their experience.

4. Maintain a 5 week lookahead schedule at a level of detail needed to identify make ready needs. Add 1 week each week.
5. Do constraints analysis on each activity on the 5 week lookahead schedule, using the constraints analysis form. Remember to mark an activity as unconstrained only if you have positive knowledge that the constraint does not exist or has been removed ('guilty until proven innocent').
6. Each week, email or fax the constraints analysis form to each subcontractor that has activities scheduled on the lookahead and ask them to provide status information.
7. Assign make ready actions as appropriate; e.g., the technical engineer will resolve RFIs, the project sponsor will expedite outstanding payments, the project controls manager will deal with contract and change order issues, etc. Obviously, subcontractors will also have make ready tasks such as generating submittals, expediting fabrication and deliveries, acquiring necessary equipment and tools, reserving labor, etc.
8. Maintain a statused and current master project schedule.
9. Involve subcontractors in producing master and phase schedules. Phase schedules are detailed plans for completing a specific phase of project work; e.g., site preparation, foundations, superstructure, skin, etc. Use the team scheduling technique in which participants describe activities on sheets that they stick on a wall, then negotiate details, sequencing, etc.

Project Checklist

1. Does the project hold weekly subcontractor coordinating meetings?
2. Are weekly work plan forms completed each week, including make ready needs and workable backlog?
3. Are weekly assignments adequately defined; e.g., is the work to be completed during the week specified?
4. Are weekly work plans used in the field; e.g., does every foreman and superintendent carry it with them?
5. Are weekly work plans reviewed in the coordinating meetings, PPC calculated, and reasons identified?
6. Is a 5 week lookahead schedule maintained, with one week added each week?
7. Are subcontractors requested each week to provide status information regarding constraints on the activities listed on the project lookahead schedule?
8. Which subcontractors provide information each week for constraints analysis? Which subcontractors don't?
9. Are make ready actions assigned each week?
10. What people carry out their make ready assignments? Who doesn't?
11. Is the rule followed that activities keep their scheduled dates only if the planner is confident they can be made ready in time?
12. Of those activities scheduled to start within the next 3 weeks, what percentage are not made ready?

13. Is the rule followed to only allow activities onto weekly work plans that have had all constraints removed that could be removed before the start of the plan week?
14. What is the project's PPC? Is it rising, falling, or staying the same?
15. What are the dominant reasons for failing to complete assignments on weekly work plans?
16. Is a master project schedule and phase schedule maintained current and updated once a week?
17. Are subcontractors involved in producing master and phase schedules using team scheduling?

Table 9.1

Activit ID	Activity Description	Planned Start Date	spons Party	Contract / hange Orde	Design AE Complete	Design Submittal	Design RFI's	Materials	Labor	quipme	Prereq Work	Weather
	Install dowel templ	12-Aug	NLB	X	X	X	X	X	X	X	Above	X
	Pour mat slab @E-	17-Aug	NLB	X	X	X	X	Concrete	X	X	Above	X
	Move tower shoring	23-Aug	Safw	X	X	X	X	X	X	Crane	Above	X
	Hard demo (Beams	30-Aug	Cal-\	X	X	X	X	X	X	X	Above	X
	One side walls	13-Sep	Peck	X	X	X	X	X	X	X	Collectors	X
	Install wall rebar	16-Sep	McG	X	X	X	X	X	X	X	Above	X
	Epoxy dowels	22-Sep	NLB	X	X	X	X	X	X	X	Above	X
	Pull Test	23-Sep	ICI	X	X	X	X	X	X	X	Above	X
	Close forms	24-Sep	Peck	X	X	X	X	X	X	X	Above	X
	Install tower shorin	23-Aug	Safw	X	X	X	X	X	X	Crane	Cure	X
	Excavate footing	13-Sep	Cal-\	X	X	X	Possible footi		X	X	Collectors	X
	Chip footings if nec	16-Sep	Cal-\	X	X	X	ecess	X	X	X	X	X
	Drill and epoxy dov	16-Sep	NLB	X	X	X	X	X	X	X	X	X
	Install rebar @mat	17-Sep	McG	X	X	X	X	X	X	X	Above	X
	Rebar template	24-Sep	NLB	X	X	X	X	X	X	X	Above	X

Zeneca-Constraint Analysis Form

9.4 Observations

The extremely high level of plan reliability achieved on Zeneca may have resulted in part from its being relatively simple, not technically but rather operationally. A relatively few subcontractors were involved[28], and few were required to work in close proximity, either temporally or spatially. On the other hand, the production control processes and techniques employed appear also to have made a contribution. Apart from the Old Chemistry Building Renovation Project, in no other case were subcontractors more intimately involved in the lookahead process or in weekly work planning. Further, the contractor's execution of the lookahead process, particularly constraints analysis and assignment of action items to remove constraints, was much more rigorous than on previous projects.

9.5 Learnings

It is possible to achieve PPC levels above 90% over an extended period of time through consistent implementation of Last Planner system techniques. Especially important in

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[28] Once the rebar installation was well underway, rarely were more than 5 subcontractors scheduled to work on the project in any week. *Safway-shoring, McGrath-rebar installation, ICI-rebar inspection, Peck & Hiller-formwork, Cal-Wrecking-demolition, National-concrete coring.* By contrast, on an interiors project underway at the same time, an average of 10 subcontractors were given assignments each week.

this regard are constraint analysis and subcontractor participation in planning and control.

CHAPTER TEN: CONCLUSIONS

10.1 Summary of Case Study Results

Data collection for the five case studies was concluded in the following order and dates, all within the period in which this dissertation was in progress:

❑ Case One-CCSR Project	Jan-Mar '98
❑ Case Two-Next Stage	July-Nov '98
❑ Case Three-Pacific Contracting	Jan-Oct '99
❑ Case Four-Old Chemistry Building Renovation	Feb-Aug '99
❑ Case Five-Zeneca	June-Oct '99

CCSR addressed the question how to apply the Last Planner system to subcontracted projects as distinct from the direct hire production to which for the most part it had previously been applied. The application was successful and piloted constraints analysis as a tool for evaluating the readiness of potential assignments and for identifying the actions needed to make them ready.

Next Stage was an exploratory case study on the application of Last Planner to design. Interruption of the project prevents drawing firm conclusions, however participants considered the Last Planner system successful and superior to traditional methods of project control. Numerous learnings were drawn from the case, perhaps the most important being the need to explode design tasks into operational detail near in time to their execution, in order to accommodate the self-generating characteristic of the design process. The Activity Definition Model was created for that purpose and has subsequently been applied extensively for the purpose of task explosion.

The Pacific Contracting case explored the limitations faced by a speciality contractor trying to unilaterally apply the Last Planner system. Diligent adherence to system rules allowed the contractor to achieve an average 76% PPC level. However, several periods of precipitously lower performance appear to have been correlated with failure of their customer projects to make work ready when scheduled, reducing the amount of work available to Pacific Contracting and consequently making them vulnerable to low PPC should they experience any plan failures at all. Another interesting finding was that plan failures within their control tended to be primarily from lack of detailed, advance operations design. Pacific Contracting has rededicated themselves to the routine use of First Run Studies in response to this finding.

The Old Chemistry Building Renovation case revealed a sustained PPC of 85%. With the opportunity to benefit from previous cases, the project team also added a very successful education and team building component to achieve this breakthrough result.

The fifth and last case study, Barnes Construction's Zeneca Project, sustained a PPC near 100%, apparently settling the question whether or not that level of plan reliability can be achieved. It is not suggested that every project will be able to achieve the same results even should they imitate Zeneca's rigorous application of Last Planner rules and techniques. The relatively few subcontractors involved during the measurement period may have simplified the coordination problem beyond the norm. However, the extensive involvement of subcontractors in planning and constraints analysis is a model to be imitated by all.

10.2 Research Question: *What can be done by way of tools provided and improved implementation of the Last Planner system of production control to increase plan reliability above the 70% PPC level?*

Review of the case studies suggests that plan reliability improves with adherence to the Last Planner system rules, with extensive education and involvement of participants, and with use of techniques such as task explosion, constraints analysis, make ready actions, shielding production from uncertainty through selection of quality assignments, and identification and action on reasons for failing to complete assigned tasks. The PPC levels recorded were significantly better than previous measurements. Previously, measured PPC above 70% was very rare (Ballard and Howell, 1997). In the latter three case studies, all achieved PPC levels of 76% or higher, with Zeneca consistently above 90%.

10.3 Research Question: *How/Can Last Planner be successfully applied to increase plan reliability during design processes?*

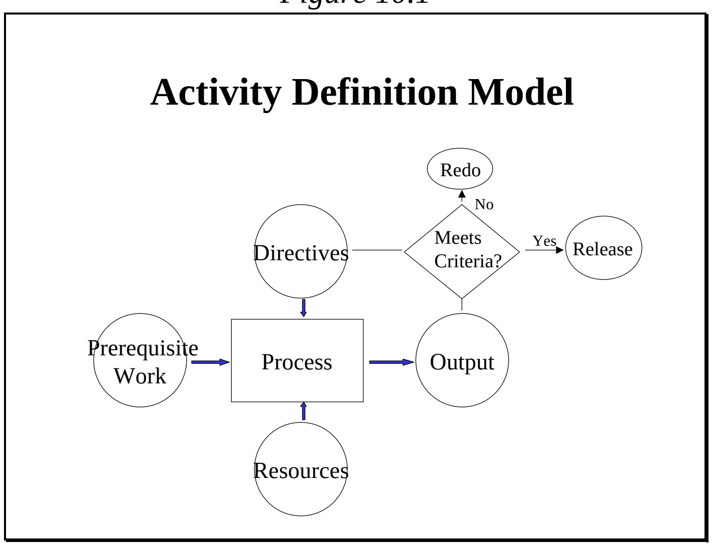
Evidence for settling this question is not so decisive. The exploratory case suggested but did not confirm that Last Planner can effectively be applied to design production control. However, the Last Planner system as now developed appears to be precisely matched to the nature of the design process. Unlike making, which covers a wide range of tasks, including making multiple copies of a single design, design itself is essentially generative. As such, a process control system is required that does not assume a simple matching of criteria and design alternatives, but rather facilitates a progressive, dialectical development of both.

Perhaps the most valuable contribution of the case was its clarification of the nature of the design process and consequently of the obstacles to management control. The primary response to those obstacles has been the development and implementation of the Activity Definition Model as a technique for exploding design tasks as they enter the lookahead process. Ideas and suggestions for further research on this question are described below.

10.4 Directions for Future Research

The case studies suggest the need for further modifications to the Last Planner System, some specifically intended to make it better fit design applications and others for general improvement. The prevalence of confusion over directives as a reason for plan failure in the Next Stage case study indicates a need for more explicit specification of the directives governing design tasks. A tool for making that specification is the Activity Definition Model[29] shown in Figure 10.1.

Figure 10.1



Activity Definition Model

ACTIVITY DEFINITION

OUTPUT represents the result or deliverable produced by performing the scheduled activity. In the case of complex deliverables, a process flow diagram is created and each of its deliverables is decomposed using the same activity definition model.

What are the DIRECTIVES governing my output, process, and inputs? To what criteria must my output conform in order to serve the needs of our customer production units? What PREREQUISITES do I need from others? What RESOURCES do I need to allocate to this assignment?

Before releasing the output to the PUs that need it, it is to be evaluated against the criteria and , if nonconforming, either the criteria are revised based on new insights into customer or stakeholder needs, or the output is revised to better meet the criteria[30].

JOINT SUPPLIER/CUSTOMER ASSIGNMENTS

A critical element for success is explicit agreement between 'customer' and 'supplier' regarding those criteria. The PU producing the output should understand how it is to be used by the customer PUs before production. Subsequently, inspection can be either by the producer or jointly by producer and customer.

Self-inspection and joint supplier/customer inspection are key concepts in the method of in-process inspection, which reduces defects through empowerment of the workers themselves, as opposed to exclusive reliance on external inspectors. This quality assurance prior to releasing work between PUs has been extended by some lean contractors to the progressing of work. Only products and installations that have passed quality control inspection can be counted as completed work, and then only if they are in the work packages (batches) needed by the customer PUs.

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[29] Although developed independently by this author in the mid-1980s, the Activity Definition Model is similar to IDEF, although arguably the concept of "directives" is different from the IDEF concept of "constraints".

[30] Conformance of outputs to design criteria is not a matter of matching. It is rather the exception than the rule that any design alternative maximally satisfies all the multiple criteria. The question is rather at what level of value must tradeoffs be made among

Recognizing the critical need for the supplier process and the customer process to agree on directives, and the objective of selecting and executing only those assignments that release work to others, it is proposed to make the supplier and customer jointly responsible for successful completion of assignments. The supplier should make sure he/she understands what the customer needs. The customer equally should make sure the supplier understands what he/she needs. Aside from assignments generated by push scheduling, in the absence of an explicit pull signal from the customer, the supplier can assume that the task does not need to be performed at this time.

REASONS CATEGORIZATION AND ANALYSIS

The reasons categories used on the Next Stage Project did not promote identification of root causes. Consequently, it is proposed to use the elements of the Activity Definition Model as the primary categories and also to provide a guide for reasons analysis that will facilitate identification of actionable causes.

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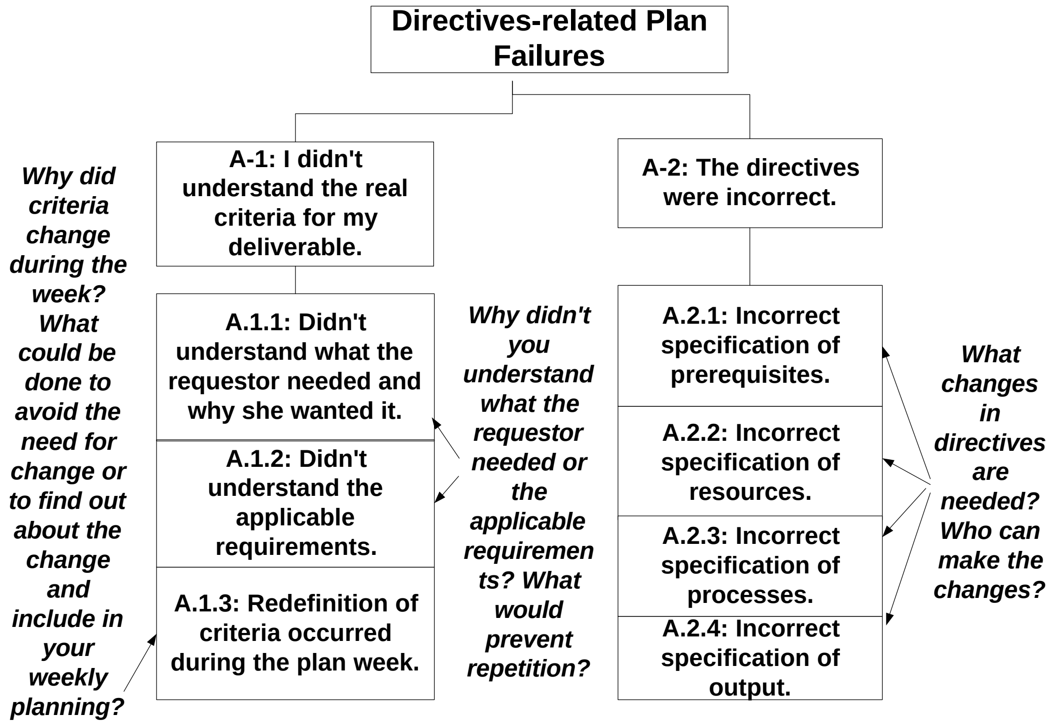
those competing criteria. Exploration of such issues is part of the future research agenda beyond the scope of this thesis.

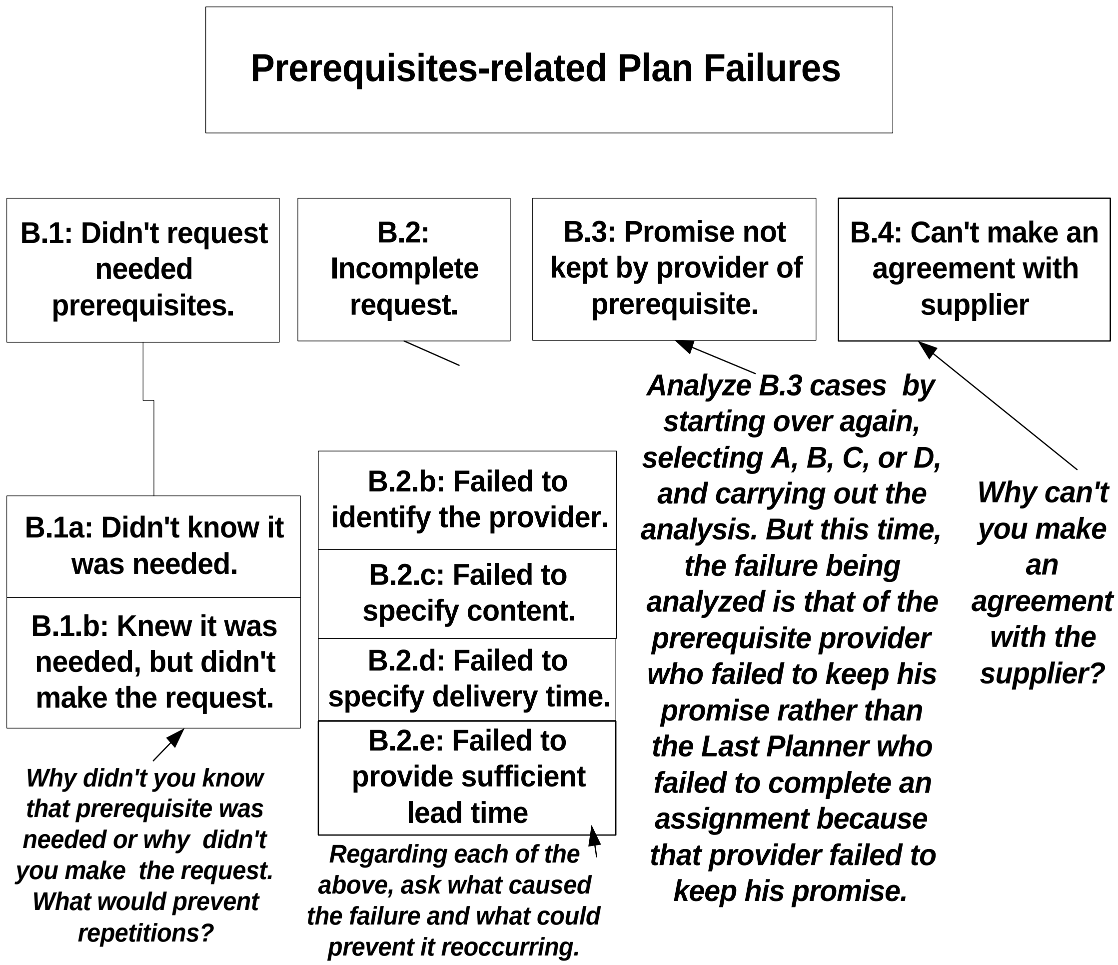
Figure 10.2



Reasons Analysis Hierarchy-Directives

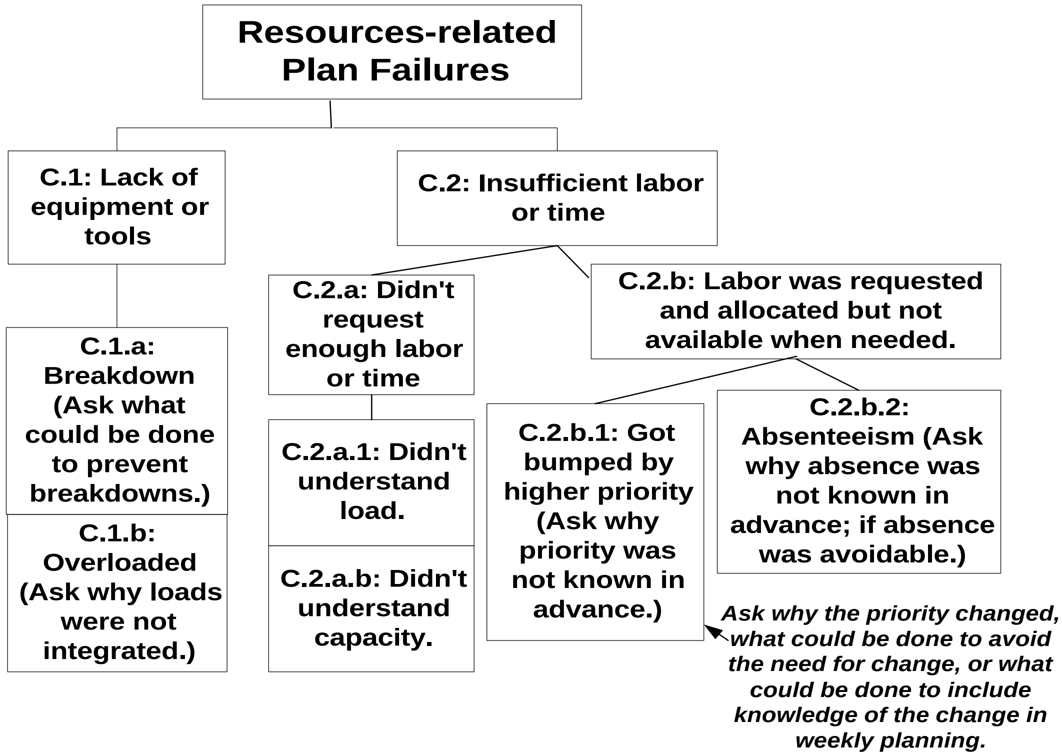
The primary categories are directives, prerequisites, resources, and process. Once placed within one of these categories, a plan failure can be analyzed in accordance with the guidelines expressed in Figures 10.2-10.5.

Figure 10.3



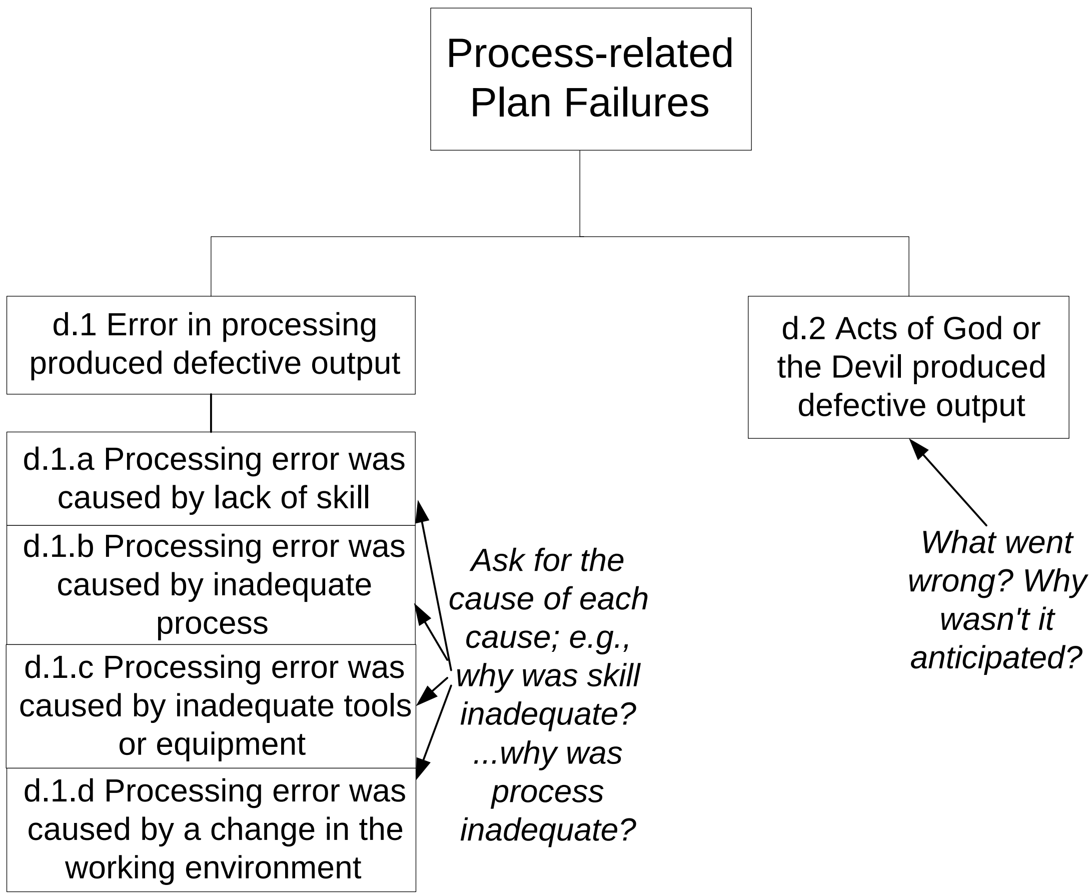
Reasons Analysis Hierarchy-Prerequisites

Figure 10.4



Reasons Analysis Hierarchy-Resource

Figure 10.5



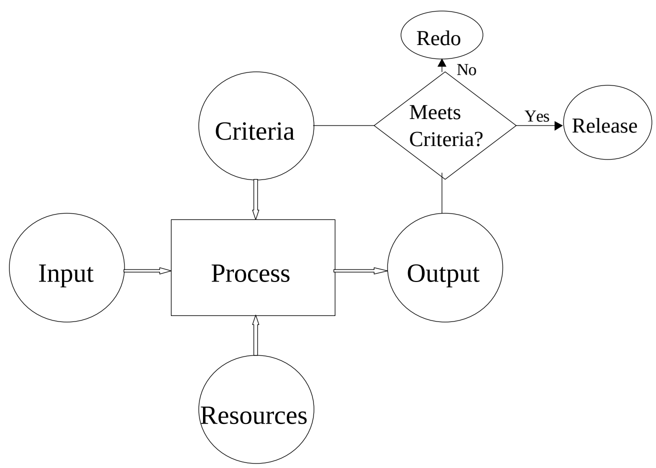
Reasons Analysis Hierarchy-Process

10.5 Conclusion

The Last Planner system of production control, improved through the case studies included in this thesis, has been shown to be effective in achieving and maintaining plan reliability above the 90% level in site installation. Applicability and effectiveness of the Last Planner system to design remains to be definitively determined, however the generative nature of the design process suggests that a control system such as Last Planner is needed, as opposed to approaches that rely on push scheduling and early selection from alternatives. Further development of the Last Planner system is suggested regarding activity definition, joint supplier/customer assignments, and reasons analysis. In addition, research is needed to quantify and understand the benefits of greater plan reliability for safety, quality, time, and cost.

GLOSSARY OF TERMS[31]

activity definition model An input-process-output representation of design tasks, supplemented by specification of criteria (entering the process rectangle from above) and of resources (entering the process rectangle from below) and an inspection process resulting either in redo or release to the customer process. The model is used as a guide to exploding design tasks into a level of detail at which their readiness for execution can be assessed and advanced.



assignment a directive or order given to a worker or workers directly producing or contributing to the production of design or construction. Example: Scott, you and Julie are to make the changes in wall locations detailed in memo #123 by the end of the week. Anne, you find out what the building authorities will require for a structural permit.

capacity the amount of work a production unit, whether individual or group, can accomplish in a given amount of time. Example: Jim the engineer can perform 10 piping stress analyses per day on average, but the analyses to be done this week are particularly difficult. He will only be able to do 7. Jim's average capacity is 10, but his capacity for the specific work to be done this week is 7.

commitment planning Planning that results in commitments to deliver on which others in the production system can rely because they follow the rule that only sound

[31] This glossary was produced specifically for this thesis. An expanded version, with some modifications in definitions, is available at <www.leanconstruction.org>. It was produced by this author and Iris Tommelein, LCI principal and Associate Professor at the University of California at Berkeley.

assignments are to be accepted or made. Example: On my work plan for next week, I have included providing Cheryl the soils data she needs to evaluate alternative substructure systems for the building. All known constraints have been removed from my task, I understand what's required and how the information will be used, and I have reserved needed labor and equipment.

constraints something that stands in the way of a task being executable or sound. Typical constraints on design tasks are inputs from others, clarity of criteria for what is to be produced or provided, approvals or releases, and labor or equipment resources. Screening tasks for readiness is assessing the status of their constraints. Removing constraints is making a task ready to be assigned.

control to cause events to conform to plan, or to initiate replanning and learning. Example: Exploding master schedule activities into greater detail, screening the resultant tasks against constraints, and acting to remove those constraints are all control actions intended to cause events to conform to plan, or to identify as early as practical the need for replanning. Learning is initiated through analysis of reasons for failing to cause events to conform to plan.

customer the user of one's output. Example: John needs the results of our acoustical tests in order to select the best location for his mechanical equipment. John is our customer because he will use what we produce.

design Design is a type of goal-directed, reductive reasoning. There are always many possible designs. Product design reasons from function to form. Process design reasons from ends to means.

design criteria the characteristics required for acceptance of product or process design. Example: The structural engineer needs both geometric and load inputs from the architect, mechanical engineer, and electrical engineer. Loads need only be accurate within 20%. Example: The cladding design must be consistent with the architectural standards of the local historical society. In addition, it must be within the 2 million pound budget and installable within a 6 week window concluding no later than 6th April, 2000.

exploding expressing a task in greater detail, typically by producing a flow diagram of the process of which the output is the task being exploded, then determining the sub-tasks needed to make the task ready for assignment and execution when scheduled. Sub-tasks are categorized in terms of the activity definition model, resulting in actions to clarify or specify criteria, requests for inputs from suppliers, and reservation of needed resources.

first run studies extensive planning of upcoming operations by a cross functional team including representatives of those who are to do the first operation, followed by methodical study, redesign of the operation, and retrial until a standard is established to meet or beat for execution of that operation. First run studies follow the Shewhart Plan-Do-Check-Act cycle, made popular by W. Edwards Deming.

last planner the person or group that makes assignments to direct workers. 'Squad boss' and 'discipline lead' are common names for last planners in design processes.

load the amount of output expected from a production unit or individual worker within a given time. Within a weekly work plan, what is to be accomplished by a design squad or individual designer, engineer, draftsperson, etc. A quality assignment 'loads' a resource within its capacity.

lookahead planning The middle level in the planning system hierarchy, below front end planning and above commitment-level planning, dedicated to controlling the flow of work through the production system.

lookahead schedule the output of lookahead planning, resulting from exploding master schedule activities by means of the activity definition model, screening the resultant tasks before allowing entry into the lookahead window or advancement within the window, and execution of actions needed to make tasks ready for assignment when scheduled. Lookahead schedules may be presented in list form or bar charts.

lookahead window how far ahead of scheduled start activities in the master schedule are subjected to explosion, screening, or make ready. Typically design processes have lookahead windows extending from 3 to 12 weeks into the future.

make ready take actions needed to remove constraints from assignments to make them sound.

planning defining criteria for success and producing strategies for achieving objectives.

plan reliability the extent to which a plan is an accurate forecast of future events, measured by PPC. For example, if your weekly work plans have a 60% PPC, they accurately predict completion/release of 60% of the weekly assignments.

PPC percent plan complete; i.e., the number of planned completions divided into the number of actual completions.

prerequisite work work done by others on materials or information that serves as an input or substrate for your work. Example: You need to know the surface area of glass, provided by the architect, in order to size cooling equipment.

production unit(PU) a group of direct production workers that do or share responsibility for similar work, drawing on the same skills and techniques. Example: a team of electrical designers and engineers responsible for a specific area or functions of a building.

productivity the ratio of the amount of work produced to the resources used in its production. Example: x drawings per labour hour.

PU See *production unit.*

pulling initiating the delivery of materials or information based on the readiness of the process into which they will enter for conversion into outputs. Example: Request delivery of prerequisite information at or before the time you will be ready to process that information. Note: what's different here is that the readiness of the process is known rather than wished. Either the process is ready prior to requesting delivery or plan reliability is sufficiently high that work plans can be used to predict readiness.

*reasons…*for failing to complete weekly assignments; e.g., lack of prerequisites, insufficient time, unclear requirements. Reasons can also be sought for failing to advance scheduled tasks from master schedule to lookahead schedule or from one week to the next within the lookahead schedule.

resources labour or instruments of labour. Resources have production capacities as well as costs. Consequently, materials and information are not resources, but rather what resources act on or process.

screening determining the status of tasks in the lookahead window relative to their constraints, and choosing to advance or retard tasks based on their constraint status and the probability of removing constraints.

*shielding..*production units from uncertainty and variation by making only quality assignments.

should-can-will-did to be effective, production management systems must tell us what we *should* do and what we *can* do, so that we can decide what we *will* do, then compare with what we *did* to improve our planning.

sizing…...assignments to the capacity of the production unit to do the work. Example: Ruben and James should be able to collect that data and analyze it by Thursday. But, I forgot, it's Ruben and Tim. Tim's not as experienced. I'd better give them an extra day.

sound assignments that have had all constraints possible removed. Example: We never make assignments that are not sound. We always check if we have or can get necessary information from others, if the requirements are clear, etc.

supplier the provider of needed inputs; prerequisite work, materials, information, resources, directives, etc.

supplier lead time the time from sending a request for delivery to the delivery.

underloading making assignments to a production unit or resource within a production unit that absorbs less than 100% of its capacity. Underloading is necessary to accommodate variation in processing time or production rate, in order to assure plan reliability. Underloading is also done to release time for workers to take part in training or learning, or for equipment to be maintained.

utilization the percentage of a resource's capacity that is actually used. Example: Because of time lost waiting for materials, our labour utilization last week was only 40%.

weekly work plan a list of assignments to be completed within the specified week; typically produced as near as possible to the beginning of the week.

window of reliability how far in advance future work completions can be accurately forecast. Example: If you can accurately forecast only 1 day in advance when work will be completed, then your window of reliability is 1 day.

workable backlog assignments that have met all quality criteria, except that some must yet satisfy the sequence criterion by prior execution of prerequisite work already scheduled. Other backlog assignments may be performed within a range of time without interfering with other tasks. Example: Completing those spare parts lists doesn't have to be completed for 3 months, but it won't harm anything if they are produced earlier, so use them as fallback or fill-in work when needed.

work flow the movement of information and materials through a network of production units, each of which processes them before releasing to those downstream.

work flow control causing information or materials to move through a network of production units in a desired sequence and rate.

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APPENDIX A: NEXT STAGE PRODUCTION TEAM KICKOFF MEETING

MTG NOTES: MAPPING SESSION, 4/98

-how do they establish need dates and estimate durations?
-how decide who should be involved in what discussions?
-Case: seat selection

(floor-mounted or riser-mounted) is interdependent with (structural pads for seats), which in turn constrains the (return air plenum), which can go either (through the floor or risers), which has an impact on (cleaning time and cost: how quickly can they setup for the next show?). As it happens, chairs come with different types of upholstery, which can change the amount and type of smoke to be removed. Points: -components such as chairs may not be offered in all varieties; e.g., although we might prefer a riser-mounted chair, such chairs only come with a certain type of upholstery that would overload current plans for smoke removal. –everything's connected to everything/designing one whole, so parts have the logic of part to whole, potentially conflicting properties, etc.

-Important to include directives in conversion maps?

-Discovered in an earlier mapping session with the structural team that could start structural engineering six weeks later and have steel delivered six weeks earlier than initially estimated. Result of having members of the steel supply chain together in the discussion: structural engineer, fabricator, and erector. Consolidated construction drawings, fabrication drawings, and shop (field erection) drawings into a single set.

-The production team and I are starting after 'schematic design'. What happened then?

-Design production consists of making calculations, producing drawings, sourcing, etc. These provide info. for further decision making, which is the big issue.

-Might use some product development techniques, e.g. functionalities, et al.

NOTES ON NEXT STAGE KICKOFF MTG 5/19-21/98

- Design completed prior to meeting: Size and function of theater (enclosed "amphitheater", 7000 seats-by Auerbach Associates, theater consultants), look and size and most materials of exterior (by ELS Architects, who were selected with theater consultant's help) and type of structure (steel frame)- they could make a model. This approximates conceptual design and perhaps some elements traditionally included in design development.
- Ed Beck assembled some members of the building teams prior to the meeting and mapped their value streams, using block flow diagramming, but switched to MS Project when he merged the maps. Lots of negative reaction to the CPM-too small and detailed, hard to read and follow.

- Teams were mgmt/support, theatrical/interiors, MEP/FP, building enclosure/architectural, and civil/structural. About half the team members had participated in the initial process mapping with Ed.
- One purpose of the meeting was to test the feasibility of completing the project by an 11/15 move-in date and, if feasible, to create a schedule for doing so. The other primary purpose was to create a team willing and able to work together.
- The first half day was devoted to introductions (very effective exercise that got people loosened up and surfaced expectations), clarification of the business objectives of NextStages, and the design history. The second half day was devoted to a brief intro. to the concepts and history of lean thinking and to the airplane game. The second day started with teams reviewing their process maps for completeness, then transitioned after some confusion into subgroups working on problems and a central group creating a milestone-level CPM for the construction phase, working backwards from the 11/15 move-in. The first half of the third day (plus some) was spent first reviewing and refining the inputs requested of each team by others, then by extending the milestone schedule through design to the present. Burning issues were recorded. Teams created more detailed internal schedules that fit within the milestone schedule. Many obstacles were identified and removed in side caucuses-“kill the snake now”.
- Participants seemed to like it. Architects and engineers said they liked getting input from fabricators and installers. Everyone liked getting decisions made on the spot rather than going through multiple loops of submission, review, rejection, rework, submission, etc.

PROBLEMS SOLVED/DECISIONS MADE

- Integrated base frame for ‘suspended’ scaffolding into ceiling grid of House.
- GO on wind test.
- Agreed to decide on audio proposal asap.
- Included cladding attachments in 3D model so can fabricate in shop.
- Agreed to start keeping a design decision log (tho’ inexplicit assignment of responsibility and inexplicit process)
- Decoupled front window and sunscreen.
- Eliminated one roof elevation.
- Substituted PVC membrane for BUR.
- ***????? Need to collect these for the record***

EXPERIMENTAL ELEMENTS

- Selection by qualifications not price
- Shared business and design information
- Open book accounting

- ♦ Group planning
- ♦ Pull planning (backward pass)
- ♦ Cross functional team including owner, architect, engineers, fabricators, and erectors/installers
- ♦ Initial attempt to integrate product and process design (needs to be highlighted and done self-consciously, with prior specification of design criteria for each)
- ♦ Production control extended to design as well as construction (future)
- ♦ Consolidation of drawings: design development, contract documents (construction doc's), and shop drawings. (Joint production of same by engineer, fabricator, and installer?)

WHAT MIGHT HAVE BEEN DONE BETTER

- Mapping with the teams in advance was probably valuable, but would have been more so if all team members were present.
- Timing: Many said this should have been done earlier, but that may have been with reference to the end date rather than to the stage of design development. Should it be done earlier in design development?
- The collaborative process is historically based on the Construction Management/Guaranteed Maximum Price (CM/GMP) approach. Subcontractors and fabricators have not previously been included in the collaboration, which was restricted to the owner, contractor, and architect, with the contractor serving as the owner's watchdog over cost during the design process. Management of the design has not been part of the process. Residue of that approach are still present in NextStages, which seems to have thought of the architect and theater consultant as having the closest relationship to the owner, then engineers, then fabricators and installers. The general contractor still will contract with the subcontractors, who will (typically) deal directly with suppliers and fabricators. Better to have installers be in the first tier around the table, then have them bring in fabricators and engineers? Should the architect be integrated with the enclosure team, since their concern is with shaping space?
- Better to have the teams use the same format for mapping so they could be more visible and more easily integrated into a whole? Better to use workmapping graphic terminology than block flow diagramming?
- Explicit attempt to integrate product and process design, with prior specification of design criteria for each.
- Explicit commitment to joint production of drawings by engineer, fabricator, and installer and sub-group planning of that process.

▪ *WHAT'S DIFFERENT AT ICE HOUSE?*

- Installers in first tier
- Workmapping

- Installers (and fabricators?) involved in schematic/conceptual design
- Explicit identification of criteria for design of product and process
- Different commercial arrangements?

NOTES TO FILE

- Design decision log: there was no record of the design brief or basis for making design and planning decisions. (What's the relationship between production planning and design? They are essentially the same kind of processes, both are design processes, but one is of the product and the other of process for designing or building the product. Ed initially resisted mixing design decision making in with scheduling, but they forced themselves together, which seems quite natural and inevitable given that they are both design processes.)
- Need to create new names for the phases of the design/construction process in order to break the grip of the conventional schematic/design development/contract documents/shop drawings model?
- I strongly suspect that many design decisions are now made with a mind to protecting what the decision maker knows is important, but without understanding what else is important.
- Everyone seemed released by the prospect of working for the good of the job as a whole, but also many said that it was just a matter of having costs reimbursable. So simple if true, but I believe that form needs to be filled with production management content a la lean thinking.
- How measure the impact of consolidating DDs, CDs, and SDs into a single set of drawings?
- How measure the impact of integrated, team design of product and process?
- How measure the impact of production control over the entire design-procure-install process?
- Need a better process for identifying and developing client values.
- Ditto for translating those values into design criteria.
- Need a way to publicize decisions that change the product or process design criteria-transparency.

WHAT TO RESEARCH AND WHAT/HOW TO MEASURE?

The cross functional team approach to integrated design of product and process. Also how values are identified, how they are translated into design criteria, and how those criteria are actually applied in the design process. *Keep documents (maps, schedules, meeting minutes), collect participant evaluations, seek hard measurements of improvement in product design, cost, or delivery time.*

Application of shielding to control of design production. Describe process, collect data (PPC, reasons, actions), collect participant evaluations, seek hard measurements of improvement; eg. productivity, durations, costs.

APPENDIX B: NEXT STAGE PROJECT TELECONFERENCES

Coordination on the Next Stage project was done largely by means of biweekly teleconferences, in which each design team 'met' in succession throughout one long day, with the management team present throughout. The notes below are those of this author made prior to or during the teleconferences of 7/29/98, 8/26/98, 9/9/98, 9/23/98, 10/7/98, and 12/16/98.

PREP FOR 7/29/98 TELECONFERENCE, 7/28/98

-The big issue was lack of pipe inverts (elevations?) at building drainage collection points.
-Should PPC measure at milestone, submilestone, action item level, or all three?
-Are “dates required” actually that or date it's thought the task will be done?
-Consider deferring decisions to accommodate uncertainty.
-How much is driven by permitting and approvals?
-Making assignments at systems team level-action items. Too detailed?
-Opaque what planning is done from which assignments are accepted; e.g., how do specialists know loads and capacities?
-Ditto what planning is done after plan period assignments are accepted; e.g., do teams or specialists create a detailed schedule for the plan period, or incorporate these assignments in their schedule along with others?
-Goal: eliminate plan quality failures. Then absorb execution failures into planning.
-Need to prioritize action items? NB: difficult to size.
-How to identify when one action item depends on another in the same plan period?
-Need to clarify purpose of the teleconference? Is it a planning meeting to identify tasks, or a meeting to status the plan and learn how to plan better?
-Need to make the planning system explicit: levels and corresponding processes.
-What experiments at Next Stage?

- -Pull scheduling; pull as work selection criterion
- -Group scheduling
- -Organization in system teams
- -How to control design?
- -How to plan design?
- -How to achieve concurrency?
- -How to develop a supply chain?
- -How to best use 3D(+) modeling?

-How might Last Planner benefit design?

-If the designer knows what work is upcoming, he/she (or others) can prepare for it: better understand the task, make ready: pull prerequisites, resolve conflicting directives, collect information. Also, design mgmt can better match capacity to load, reducing idle resource time and overproduction. Avoid having too many or too few specific skill sets to do the available work.
-If more assigned tasks are sound (ready), less designer time is spent switching between assignments. Also, assignments can be more often completed when scheduled, better advancing the design project.

TELECONFERENCE, 7/29/98

-See AA07.01.8.03 “Resolve building storm/sanitary site collection points and pipe inverts.” [my comment: need elev. of storm drains and above from ME] This was assigned as a group task to the mechanical engineer, civil engineer, project manager, and the plumber due 7/10 and subsequently rescheduled to 7/28. See also AA07.15.98.09 “Complete site drainage design criteria” [my comment: need pipe inverts at bldg collection points]
-Poor definition of assignment in AA07.15.98.16 “Meet with Lone Star Park to discuss terms and conditions for purchasing their borrow material.” Marked completed, but output unclear.
-NB: importance of really understanding the action: -what’s it mean? –what’s prerequisite? –how long to perform once sound?
-AB07.01.8.08 wasn’t pulled, so due date was deferred to 8.12.98.
-Perhaps an example of lack of definition: AC07.15.98.02 “Resolve insulation requirements for shell of the building.” Failed for lack of info from ME on heat loads. Didn’t ask them specifically although they were included under “Action by”.
-Completion of 3D model impacted by multiple minor changes. Driver is intention to use model to produce fabrication drawings. Loading info. is needed later, but need roughout loads up front. Geometry is needed first—was delayed by changes in seating platforms.
-“value stream had no cushion.” Need to redo value stream to capture that learning?
-Interesting example of the complexity of actions lurking beneath a seemingly simple assignment: AD07.15.98.07 “Coordinate location of proscenium deluge system with other systems.” Questions that arose in discussion: ‘Does the curtain have a membrane that will require wetting both sides? How to control the deluge system? Possibly applicable code requires heat sensors on stage-not yet provided. Code not explicit about sensor locations, etc.’
-IB07.15.98.03 “Schedule for steel fabrication may be too tight.” Concerned about tolerances in design and construction, especially regarding the seating platforms.
-Apparent problem: ‘Committing’ to an action that has predescessors, perhaps in a chain, some of which do not have identified prerequisites. A constraint: difficult to know very far in advance what that logic is because it is developed as each step is taken?

-NB: Important to note when a design criterion is being produced? Also…to track decisions re design criteria?
-Make 'issues' deliberately include next 1-2 plan periods and use to develop definition of the actions needed?
-Are most/many failures from lack of definition? If so, need a make ready period in which….
-Clearly the actual planning/replanning rhythmn is faster than biweekly.
-Biweekly: *Adjust milestone (and submilestone?) schedule *Each team statuses & categorizes the previous plan period. *Each team develops a work plan for the next plan period. *Teams "meet" to merge work plans. *Hold this meeting, then finalize team workplan and coordinate by phone-"Can you…?"

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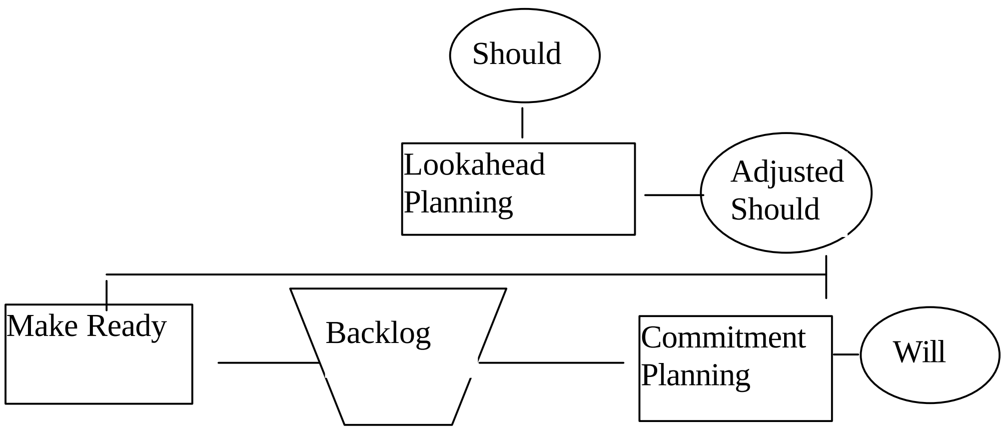
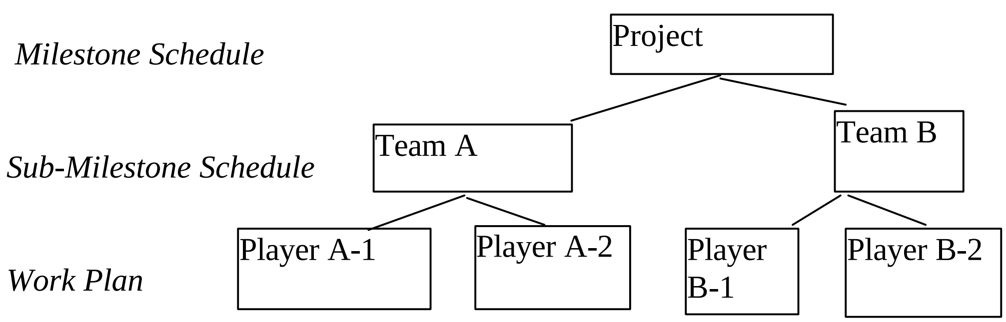


*Does this structure work for design? Are strong commitments possible?
*Design tasks are often closely coupled in time, so lots of 'deliveries' are needed within the plan period.

-What statusing and categorizing can be done by individual players? Is a teleconference the best way to do this?
-Why didn't Jerry ask Gary for the piping inverts?
-



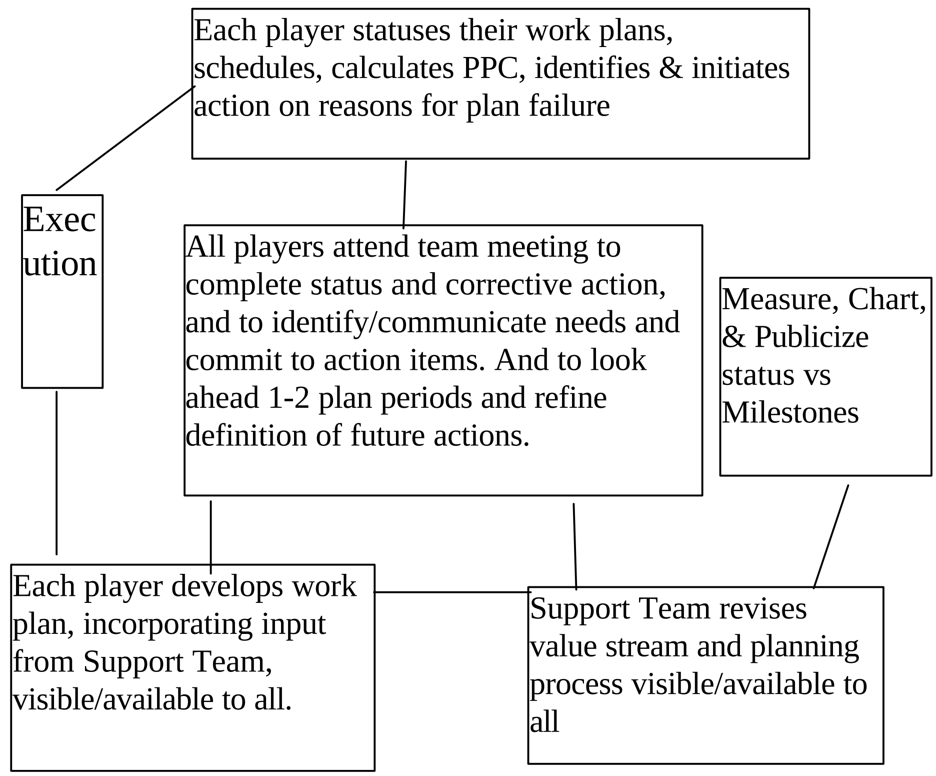
*Each player is responsible for pulling what they need from others?

-Perhaps the key virtue in design is rapid replanning rather than plan reliability.

-A key is understanding each other's needs and the value stream.
-<u>Levels of Schedule</u>

- ♦ Milestone Schedule/Value Stream
- ♦ Submilestone (work release between teams)-PPC measured
- ♦ Work Plans (actions by players within teams)-PPC measured for use by player; reported to project as indicator of reliability.
- ♦ Action Item List
- ♦ Decision List
- ♦ Issues List
- ♦ Player schedules

-



-Whoever needs something from someone else is responsible for precisely defining the need and should pull it from them.
-How to confirm pull? Must someone else give you an order or should each player work independently toward the milestones unless he receives an order? Share work plans so others know what you're doing.
-It's really hard to know the design criteria for specific design products.
-Many action items result from needs for input info.-loads (structural, heat, energy, etc.), dimensions, etc. Fits with problem solving model?
-Might help if they had a limited glossary of action types: 1) determine design/decision criteria, 2) understand the design task and process, 3) collect input info., 4) generate alternatives 5) evaluate alternatives, 6) select from alternatives/decide, 7) approve…
[activity definition model].

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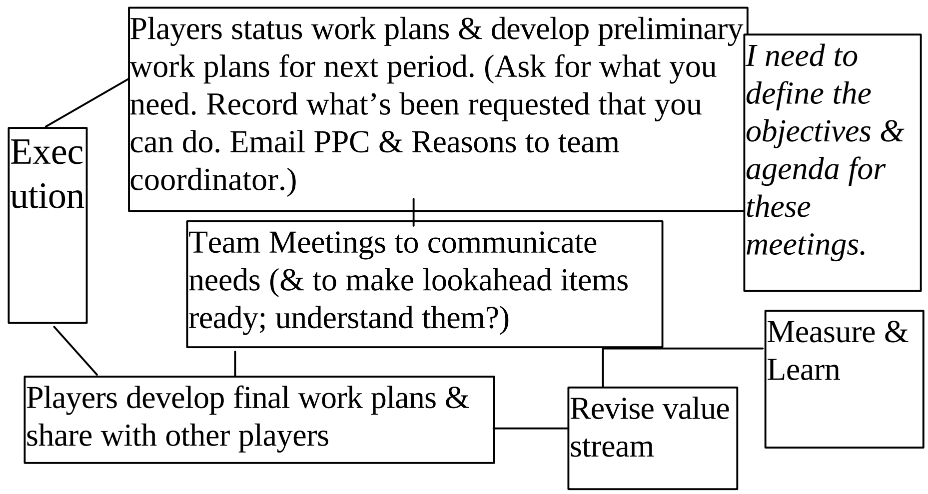

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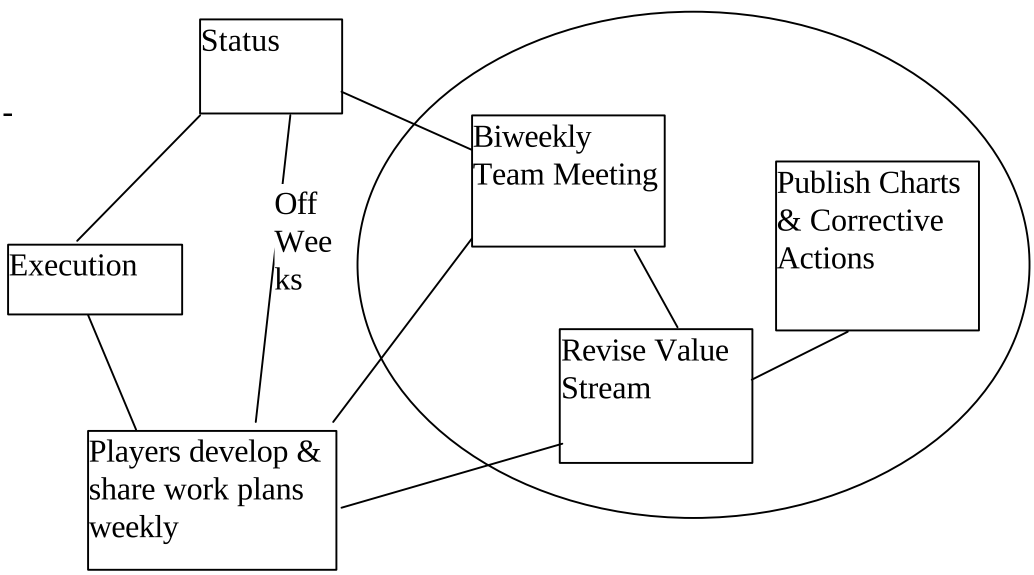


-Still need to decide who does what design (detailing?)-engineering consultants or speciality contractors?
-These don't all look like commitments to me.
-Definition of action items is a problem. Don't fully understand what's being pulled (what's needed), design/decision criteria, prerequisites.
-'Make ready'-applied to design-starts with understanding the design task, process & dependencies, & criteria. Should be done prior to work entering the plan period.
-Are all players developing work plans that include both action items and work needed to support value stream unless modified by pulls? Urge them to track

their own PPC and act on Reasons. Urge them to come to meetings with action items statused & categorized and perhaps with something to share about corrective action.
-Need to update value stream each 2 weeks.
-Make system transparent.

TELECONFERENCE 8/26/98

-AA08.12.98.01 "Revise and submit site drainage…" is a follow-on from the earlier added collection points issue. Civil engineer still waiting on roof drains info from mechanical engineer. AA08.26.98.10 "Second set of overflow drains connect to main system…." Discovered apparent code requirement for a separate downspout for overflow drain until it turns underground; previously misunderstood. Project mgmt believes the city will accept an alternative design if well argued. Some concern expressed that the requirement may have good reason; i.e., redundant protection of roof from overloading and collapse. Learning: important (always?) to understand the basis for the directive. NB: Decision point when 'negotiating' directives: 'fight or flee'.
-Seems like good discipline in action item identification etc.
-When step back and look at the master schedule?
-Example of criteria clarification and importance: AA08.26.98.08 "Contact TAS/Barrier Free Texas to initiate early review and resolve the filing and approval process." CE discovered that they wanted minimum travel from handicap parking to front entrance, hence a new action item to conform design to this criterion. Previously assumed less stringent requirement.
-Not identifying or analyzing reasons. How to best do so?
-AB08.26.98.04 Computer memory had to be added to run the model. (Str. Eng. hasn't done 3D model before, or smaller?) Str Eng is producing drawings as they build the model. Need to complete model in order to determine member sizes.
-Need order mill steel 1 month before breaking ground—decision confirmed.
-Would be neat if could easily and quickly see the consequences of choosing week n or week n+1 for completion of an action. If could, then could choose sometimes to expedite, add resources, etc. in order to do earlier, if desirable.
-Example of interdependencies: AC07.15.98.02 "Resolving insulation requirements for shell of the building." Sound/power ratings of cooling towers will drive amount of insulation or double sheet rock.
-Good example of detailed info needed by one specialist (cladding contractor) from another (architect): AC08.26.8.02 "Clearly identify on the concept drawings the location of each color, and determine quantity of the vertical, horizontal and smooth panels so the cost for custom colors for each type can be assessed."
-Ongoing saga of the fire protection curtain: AD08.26.98.03 "Follow up on proscenium deluge system meeting…." NB: poor definition—"follow up". Really a life safety issue that belongs in Theatrical. Opaque curtain is allowed by code but is not customary.

-Waiting on food service consultant added late to team-Creative Industries. Didn't expedite getting equipment layout from them. Supposed pull was from ME, but he didn't realize that.

TELECONFERENCE 9/9/98

-How well do participants think this management process is working? Useful to track PPC and reasons? Any actions taken on reasons? How much time is spent and wasted (respent) re clarity of directives?

-Design output(s)	Criteria	Authority	Advisors	Basis
parking lot layout	provide handicap w/ min travel to bldg entrance	city?	Texas Access	
roof overflow prot. drains systems	separate downspout from overflow drain until it turns underground	city	-	ind.

Pull request	Reason needed	Requestor	Requestee

-Critical to find the 'hard' points of the design space. If cost limit is exceeded, may have to sacrifice functionality, capacity, or 'quality'.
-Must be discouraging that construction keeps slipping. How to use the added time? When/how to stop?
-NB: Different issues and tools may be useful for different disciplines. E.g., civil seems to depend heavily on permitting requirements. Try to list design outputs and applicable requirements, and criteria (must have/nice to have) for each discipline and system team.
-There was a mention that ELS would make their next milestone, indicating some attention is being paid to the milestone schedule.
-A different kind of problem—agree on criteria, but disagree on what satisfies them. Or, designed to one set of criteria, but a specialist designs to a new set (e.g., acoustical insulation). Specialists are advocates for specific criteria!
-How often do we not fully understand the design decision to be made? E.g., select and locate mechanical equipment to suit requirements for loads at least cost, then factor in acoustical criteria and discover a cost of $200K in insulation, wall type, etc.
-Interim assessment of Last Planner?
-Reasons analysis and action-how to?
-Record criteria?…in decisions log?/or activity definition 'explosion'
-redraw design value stream, incorporating learnings
-record pull in action items log so they can expedite and clarify?

-Team tackle increase in acoustical-related costs: architect (visual, space layout), acoustical consultant (calculates mitigation techniques), mechanical engineer (point sources). Acoustical consultant calculates need for 50 foot masonry wall to provide desired acoustical insulation from mechanical equipment noise. Alternative is to select quieter equipment, relocate equipment, or shield equipment locally.

-Issue: Bass Performing Arts Center had a target NB=18, but actual turned out to be=13. How to ensure not overspending?

-NB: teams are driven by specific milestones; e.g., "complete 3D model" now appears to be the guiding star for the structural team. What's driving each team in each phase? Equipment selection must be a big issue for mechanical and electrical. Also equipment locations, which includes ducting, etc.

-Need a schedule for completing the design. Calculate from a supposed 11/15 construction start date?

-Seems like if we better understand the interdependence of decisions, we could better manage the design process.

-NB: highly specialized consultants are expert in: 1) the real requirements; wiggle room-what can be negotiated; alternatives (wind tunnel tests to determine 'actual' wind loads), 2) ways of meeting the real requirements plus desired criteria, 3) sometimes expertise or technological means for calculating or assessing alternatives; e.g., a testing lab. or special software.

-AA08.12.98.01 Continuing saga of site drainage—CE didn't receive info. needed. Apparently no pull. Wasn't needed in plan period. Still don't know if there is an unavoidable code requirement for multiple leaders, but city is confident they can allow us 'what we want'.

-Example of one period action item requiring prerequisites from another scheduled for same period: AA09.09.98.08 and …09. 8 was to get test data on possible borrow material. 9 was to make a rec from 3 alt pavement designs. Why did we think we could do this in the period? May have assumed local material could be used. Obviously expected to get test results sooner than today, when CE actually received them.

-Handicap parking saga: Must reconfigure; put more handicap spots in front of bldg.

-CE didn't complete many action items during the plan period. What hours were spent and what was accomplished?

-Considering change in seating. No change to building structure expected. How big a deal? Decided to defer 3D model transfer until a decision on seating is made.

-Metal color samples saga: AC08.26.98.01. Manufacturer waiting on receipt of third of three color samples from paint company.

-Confusion re criteria: AD09.09.98.07. EE thought theatrical didn't want transformer in dimmer room, but actually didn't want it in amplifier room. Even so, unclear what transformer location is best.

-Deluge curtain saga: Determined applicable code—NFPA (Nat'l. Fire Protection Ass'n.) 13.

-Rough categorization of decisions in Decision Log: design itself, problem definition, process, needs definition.

-No review of PPC or reasons within the meeting.

TELECONFERENCE 9/23/98

-What can be done to improve sequencing, make ready (soundness), and sizing?

-Revisit the design value stream to make sure we understand the best sequence.

-Explode master schedule activities as they enter the lookahead window. Use activity definition model to make sure we understand the scope of activities.

-Identify who/what is pulling each assignment in the lookahead.

-Have pullers pull.

-Issue minutes by Friday after Wednesday meetings.

-Have assignees apply assignment quality criteria; empower them to say 'no'.

-Learn how long tasks actually take and adjust future estimates. Also, be con- servative.

-Understand the consequences of failing to complete assignments, so can take better risks.

-Be more precise in the statement of assignments. Avoid "review", "follow up", etc.

-Analyze reasons to actionable causes. Use 5 Whys.

-I'm uncomfortable with the idea that these meetings produce assignments. Often need additional definition before can apply quality criteria. Why not allow changes negotiated between 'suppliers' and 'customers', with notice to all? In other words, make planning continuous rather than periodic?

-Clear need to issue 'minutes' immediately after each meeting. Players not using action item log.

-Decided to 'target' completion of wall/acoustic design (AB09.09.98.0?) although not sure will complete. Should understand implications of failure.

-Dangerous to complete design without knowing the users of the facility?

-It's not bad to do more than what's on the action item log. It is bad to not do what's on the log. E.g., the architect chose to spend available time to complete glass and stair design package, and let slip detailing external wall mockup. Could have tagged latter as a workable backlog item.

-Communication 'preferences': some people are not comfortable with multiple channels: phone, email, fax, etc.

-Not being colocated is a problem. Personal connections, ease of communication, getting the right people together, lack of unplanned meetings (water cooler, corridor).

-Is there a list of equipment with vendor, price, weight, energy requirements, heat generated, etc?

-Is/Should there be a statement of design criteria for each system, subsystem, component? Is the Decisions Log sufficient? Per architects, some theatrical consultants produce room documents/books.

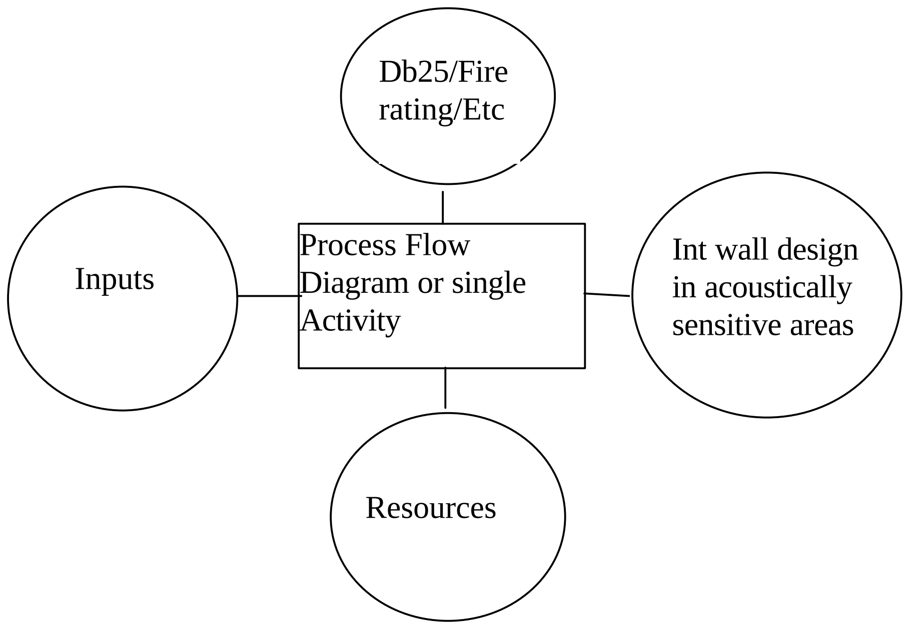
-My actions:

-Analyze reasons with architect.

-Understand how individual planning systems hinge to centralized planning system. When/how do players match load to capacity? Do they check that match before accepting assignments? Each player has work to do that does not appear on the master schedule and may not be pulled externally.

-Identify action items that involve clarifying or generating design criteria.

-Develop examples of activity definition models



-Could do for seat layout, cladding, roofing, etc.

-First screen in evaluating/generating alternative designs is—does it meet design criteria? 2nd concern: is one preferable in re nonbinding criteria such as constructability, ease of acquiring materials, cost, time, etc?

-Need a category "Not pulled"?

-Pull what you need: 'customer' processes not consistently expediting what they need from 'suppliers'.

-Collectively define the task up front; who leads?

-<u>Item No.</u> <u>Item Desc.</u> <u>Action by</u> <u>Pulled by</u> <u>Revised Date</u> <u>Date Completed</u> <u>Need This Plan Period?</u>

-I would like to see how each player identifies and tracks their work and how they use the planning system. Are players able to make good commitments; balance load and capacity?---One weakness appears to be lack of common understanding of action items at close of meetings.

-Type as we go and email instant for review of wording.

-Design work can reveal more definition of a design activity. E.g., handicap parking: developed a layout before fully understanding the design criteria.

Investigation revealed that change to conform to actual criteria may require more fill material.
-Discussion: Civil has had high PPC. Because of external deadlines? Is there an issue of commitment? On the contrary view, I suggest we find out:

-Are those accepting action items applying quality criteria?

-Are players able to accurately match load and capacity?

-Are players able to accurately predict 'deliveries'? Do they expedite deliveries?

-Are players able to sequence activities to best meet project objectives?

-Analysis of reasons: 89/125 (71%)=40 (prerequisites)+24(insufficient time)+25(conflicting demands). Regarding prerequisites, we're apparently not very good at predicting or causing delivery of needed inputs. Regarding insufficient time, we apparently are not very good at estimating the time needed to accomplish specific tasks. Regarding conflicting demands, may need clarification. Does this mean unexpected demands or failure to accurately quantify multiple demands? If the former, there's a problem with identifying priorities even 2 weeks ahead of time. If the latter, same problem as with insufficient time. (NB: some "prerequisite"-based failures are ripple effects; failure of prerequisites within same plan period.)

1.Sequence: identify priorities 2 weeks ahead-demands on time and relative priority of demands. Do we understand the design process? Can we identify what needs to be done in what order? Do we understand what's involved in doing each of these activities?
2.Soundness: predict deliveries; expedite deliveries
3.Size: quantify time needed to accomplish tasks

TELECONFERENCE 10/7/98

-Blueline/Online coming up. Will post minutes thereon this time.
-Added administrative assistant to speed production of minutes.
-Target start date now 12/1/98, but February is most likely.

Civil

-CE confused re pull for first item. Thought it wasn't pulled, but is given target date. In any case, still lacks storm drain info.
-Easement requested. Added to final plat. Includes electrical yard. CE will copy Fisk Elec and Texas Utilities. Curt asks if it goes through landscaping-obviously the architect has not been involved-requested copy. Still need Texas Utilities acceptance of our elec yard layout. –Have agreement to tie overflow drains into ceiling verticals. Making proposal to city.
-For action item 05 we need the mechanical engineer. Civil has to conform his plans for additional drains. (This issue just refuses to die!)
-Grand Prairie school district has 30,000 CY of fill material about 4 miles from our site. Sandy clay. Pi of 21 & 25. Suitable for cement stabilization. Asking for proposals. Est. cost of handling $5/CY. Est. cost of material $1? Our budget is $5 total for select material. This is not select material. Would be $1 over budget.

May be able to mix with cheaper material from other sources. Not ready to select pavement design.[NB: Estimates become controls; e.g., $5/CY for select material.]
-(11) General Electric Service scope of work—need Fisk Electric.
-55 foot light pole is agreed.
-(4) Revised handicapped parking plan and posted 9/25.
[Is an issue showing interdependence of action items?]
-Issues:

-Life Safety pkg.: ELS has issued a draft and is collecting comments. Asked to receive by 9th. Life Safety consultant back next week. Target issue date is the 16th.
-Timmel to ask TU what they propose to give us.
-Lone Star borrow material not yet pulled.
-Lone Star easement—Halff has sent note requesting.
-No new issues from review of site value stream.
-Statusing site value stream

-Erosion control plan filed? Yes.
-Final plat complete? Yes. Sent to Kaminsky's attorney for review.
-Grading permit. Not applied, but should be automatic when needed.
-Down to closing on land and filing for permits.
-Land trade with District-need to happen 10/14.

-4 Week Moving Average PPC=61%. How to improve?

Proposed to analyze in depth a sample of failures from each team, selecting only from top 3 reasons. Could a team representative perform 5 Whys on 3 failures of each of the 3 types and report to Ballard?

-Seating configuration: curve schema GO pending cost estimate by Bruce Perry. Bruce: No difference in cost for stud framing (Merrick Brothers) between segmented and curved. Estimate: $10k for layout. NB: Bruce careful to state his assumptions re the design./Need return air openings—to be worked out. Better to form in concrete or steel?/ELS will detail each type of riser mount heights—3 types./Acoustical issues? ELS thinks not, but will check with consultant./Decision: Change platform design. Agree will cost <$200K. 5 weeks to price in detail. Need to work out framing requirements. Merrick says 8 feet. HW says 20 feet. Same type framing? [Watch this one. How well did we identify the ripple effect of this design change?]

Structural:

-Riser issue: height of riser, material, attachment method; Merrick, Haynes-Whaley, Irwin, ELS.
-3D model on hold for revisions to seating platform. Need to complete before final estimate.
-NB: Robert is clearly pulling duration estimates from his nether region. Often requests for info. have the flavor of demands for commitment—or just plain wishful thinking.]

-Prefab stairs. Can use for fire stairs but lobby stairs must be detailed by structural engineer.
-Structural and foundation permit date will be pushed back by 2 weeks to 11/24. [Need to do more process mapping! Harder to do at a distance.]
-Update from Haynes-Whaley, Str. Eng: Good meeting with ELS last week. Finalizing fly tower. Need input from Jaffe re concrete pads for mechanical eqpt. on low roof. Offline discussions to be held on interior wall design. Steve of CC wants Peterson to install tall house wall-discuss with HW. Peterson to install all purlins.
-[NB: The traditional method seems to be for each discipline to push forward independently, then adjust as as inputs are acquired from others. To what extent do they proceed on assumptions or pull/wait for what they need?]

Skin:

-NB: Joel asks each team/person if they need anything they don't have.
-Metal samples and price are in hand. Price not an issue.
-Wall mockup pkg. from ELS: each c. 10'x20' high; to show 3 conditions; e.g., vertical panels and soffits. Locate offsite on adjacent property-Kaminsky's. Also applies to construction trailers? Can defer grading until last minute? Cost: ELS to provide simplified drawings. [Why not do a computer model?]
-Need some concrete under rooftop units on low roofs, but no masonry wall. Not sure re no. of layers of gyp. board in stud wall. Only possible exception is unit serving dressing room. [Why has this been so hard/taken so long to resolve?]
-ELS to give CC the change point from X to Y at back of house.
-Material for low canopy roof will be visible from lobby. Need different material?

MEPF:

-How many items of kitchen eqpt. do we now have? No. of supply and exhaust fans have increased from 6 to 24. Why? Amy couldn't say. To handle offline.
-Impact of smoking area on exhaust.
-8400 feet of 2 inch slots in seat framing.
-Biggest issue to resolve is concessions.
-Acoustic shielding of mechanical units: when deal with duct noise? When will duct layout be done? 10/12: main duct runs laid out and sized.
[Collecting status info., clarifying current state of design: "Are there any mechanical units on the other side of the building?"]
-NB: NC25 not maximum in lobbies and cheap seats.
-Fire pump: What available water pressure? Need a pump? Yes-125hp. Should be served off emergency generator? Fisk to examine.
-Locations/sources of cable, telephone, etc? Need to meet with phone co.
-How many phone outlets will be required? No. of incoming lines? Need to show on floor plan-phone, data, closed circuit TV. Bill Cambra.
-[Civil engineer seems to handle all ins and outs from property.]
-Requirements for cable TV? Comes into telephone data room. Satellite dish on site? On roof backstage?

-Before addition of loading dock, first floor plans showed gas meter location which now doesn't work. Where is gas meter now? Where to bring gas to?
-U.G. plumbing at perimeter: lower priority-work to 5 week schedule. [The issue seems to be what's needed in order to design the underground plumbing.]
-Duct designer needs seat redesign backgrounds. Need to evaluate but add 2 weeks for design change (10/26).
-Lighting heat loads complete. Emergency power loads need to be updated-now 230 hp, but kitchen eqpt not settled. Also normal loads.
-Mtg on structural issues at ELS last week got chunks of work done. [colocation issue!]
-[watch for interdependencies/gnarly issues: kitchen, seating, acoustics]

Pricing:

-Cost of project has clearly risen, but need definitive estimate. Becoming <u>the</u> hot item.
-Estimating is based on drawing takeoffs. Want reproducibles.
-Electronic transfer hasn't worked. Don't transmit error free.

TELECONFERENCE 12/16/98

-Current categorization of reasons does not reveal actionable causes.
-Has pricing diverted attention from scheduling?
-Why is the estimate so important? Amount of $ needed; financing. Fix GMPs for each player.
-Don't always understand the decision chain; e.g., color selections would seem to be needed late, but may be needed earlier to match exterior and interior colors.
-ELS considering board vs stone wall to lower cost. But not much such matl. Would violate City's architectural review? Considering using inside to replace something else. May be more labor than stone. NB: Functionalities are revealed by technology and component selections. E.g. need 10 by 10 area for scissor lift to be used to relamp lights in high lobby ceiling. Could have chosen lights that could be lowered for relamping.
-The longer the plan period, the more difficult it is to defer commitments until receipt of prerequisites, rather than betting on the come. The shorter the plan period, the less lead time is available for planning future periods.
-Missing water and electricity in parking lot.
-Overflow drain issue: now 2 separate systems <u>are</u> required (issue that won't die!).
-NB: local differences—CHPA didn't know gas meter size beforehand.
-scheduled new item: begin fire protection drawings by 1/15. 6-8 week design period. Need for permit. Focus on distribution system rather than sprinklers.

APPENDIX C: NEXT STAGE ACTION ITEMS LOG

The following log was the primary coordinating device used on the Next Stage project. Each teleconference was given a sequence number, beginning with AA07.01.98, indicating the design team (AA indicated Site/Civil, BB indicated Structural, etc.) date of the teleconference. Action items that were identified within each teleconference were given a sequence number such as AA07.01.98.01. Assignment of action items was made to the various companies participating on the project by use of their initials, e.g., ELS stood for the architectural firm. The date required was specified. If an action item failed to be completed by the required date, a reason number was (usually) indicated in the column labeled RNC, and a new required date listed in the column Date Required. Once completed, a date completed was provided and the rows devoted to the action item were darkened.

1. Lack of decision
2. Lack of prerequisites
3. Lack of resources
4. Priority change
5. Insufficient time
6. Late start
7. Conflicting demands
8. Acts of God or the Devil
9. Project changes
10. Other

Action items are grouped by design team, sequenced in the order Site/Civil (AA), Structural (AB), Enclosure/Architectural (AC), Mechanical/Electrical/Plumbing/Fire Protection (AD), Theatrical/Interiors (AE), and Project Support (AF).

Linbeck Next Stage Development

The Texas Showplace

Action Items Log

As of December 2, 1998 Project Progress Meeting   Revised: 12.14.98

Date Originated-Item No.	*Item Description*	*Action By*	*RNC*	*Date Required*	*Date Completed*
A. Site/Civil					
	Texas Accessibility Standards:				
AA07.01.98.01	• Provide TAS requirements to ELS	HA		07.07.98	07.07.98
AA07.01.98.02	• Identify preliminary and final TAS review process.	ELS		07.14.98	07.14.98
AA07.01.98.03	Resolve building storm/sanitary *site collection points* and pipe inverts; still lacking inverts. *Coordinate profiles with water line surrounding building to be deeded to City*.	CHPA/HA/ *LCC/TSPH*	2	07.10.98 07.31.98	08.02.98
AA07.01.98.04	Develop site and parking lighting *compatible with Lone Star Race Park* for site plan submission for Planning and Zoning approval *(Control Road "B")*.	TEE/*FE/ HA*	6	07.14.98 08.12.98	08.12.98
AA07.01.98.05	Provide color rendering for submission for Planning and Zoning review/approval; resolve landscape issues (IA07.01.98.05).	ELS	7	07.14.98 07.27.98	07.27.98
AA07.01.98.06	Transmit Site Plan package (2 sets) to LCC.	HA	7	07.14.98 07.17.98	07.17.98
AA07.01.98.07	Review/Revise value stream diagram.	HA		07.14.98	07.14.98
AA07.01.98.08	Provide/confirm building electrical load for site utility plan.	TEE/HA/ FE	7	07.14.98 07.17.98	07.28.98
AA07.01.98.09	Provide invert elevation for storm water pipe at loading area.	HA		07.14.98	07.14.98
AA07.15.98.01	Provide recommendation for Accessibility Specialist to ELS	HA		07.17.98	07.15.98
AA07.15.98.02	Contact power company for project information.	TEE		07.20.98	07.20.98
AA07.15.98.03	Have traffic impact analysis completed.	HA		07.20.98	07.20.98
AA07.15.98.04	Send copy of traffic plans and traffic impact analysis to Lone Star Park.	HA		07.20.98	07.20.98
AA07.15.98.05	Complete conceptual point grading plan around building.	ELS	6	07.20.98 08.12.98	08.11.98

AA07.15.98.06	Resolve grading at diagonal wall with landscape architect.	ELS	6	07.20.98 08.12.98	08.11.98
AA07.15.98.07	Obtain Accessibility Specialist list from Texas Dept. of Licensing.	ELS		07.22.98	07.22.98
AA07.15.98.08	Select an Accessibility Specialist	HA/ELS		07.28.98	07.28.98
AA07.15.98.09	Complete site drainage design criteria	HA	2	07.24.98 08.12.98	08.12.98
AA07.15.98.10	Complete off-site civil design of City required items of work (IA07.01.98.04). *Submitted comments, not required for City Council, but for Plat Approval (Approved at Planning and Zoning meeting).*	HA		07.24.98 09.09.98	09.09.98
AA07.15.98.11	Complete Road "D" plan to support easement and operating items negotiations with Lone Star Park *(Received conceptual design approval 07.24.98)*.	HA	2	07.24.98 08.12.98	08.12.98
AA07.15.98.12	Resolve and provide presentation materials to City Planning for internal staff review.	HA		07.24.98	07.24.98
AA07.15.98.13	Planning Department internal staff briefing (IA07.01.98.02).	NS/HA		07.27.98	07.27.98
AA07.15.98.14	Confirm city mailings/posting on-site notice announcing zoning revision hearing (IA07.01.98.03).	NS/HA		07.27.98	07.27.98
AA07.15.98.15	Determine amount of project requirement for borrow material.	HA		07.28.98	07.27.98
AA07.15.98.16	Meet with Lone Star Park to discuss terms and conditions for purchasing their borrow material.	NS/LCC		07.28.98	07.27.98
AA07.29.98.01	Resolve date of City Council hearing; coordinate date with Economic Development assistance package hearing/approval.	NS		07.31.98	08.12.98
AA07.29.98.02	Dialog with Lone Star Race Park manager regarding lighting fixtures.	TEE		08.03.98	08.12.98
AA07.29.98.03	File original drawings/graphics for Planning & Zoning meeting (IA0701.98.07).	HA		08.03.98	08.12.98
AA07.29.98.04	Meet with Grand Prairie building officials to determine multiple permit packages and document requirements (IF07.15,98.05).	ELS/HA/NS		08.06.98	08.06.98
AA07.29.98.05	Planning and Zoning hearing/approval (IA07.15.98.01).	NS/HA		08.10.98 08.24.98	08.24.98
AA07.29.98.06	Decision regarding rescheduling 08.18.98 City Council hearing	NS/ELSHA		08.12.98	08.12.98
AA07.29.98.07	Complete water line/easement design around building.	HA		08.12.98	08.12.98
AA07.29.98.08	Resolve construction start date (IA08.26.98.01).	NS		Issues Log	08.26.98
AA07.29.98.09	Resolve electric power supply options, permanent and temporary. *M. Dickman met R. Cox of Texas Utilities (IA08.26.98.02)*	TEE/HA/LCC		Issues Log	08.26.98

AA07.29.98.10	Advance terms and conditions for purchasing borrow material from Lone Star Park (IA07.01.98.09/IA07.15.98.06). *Evaluate material. Pull is the GMP. Est. 50,000 yds select material.*	NS/HA		08.12.98 09.09.98	09.09.98
AA07.29.98.11	Prepare revised Site/Civil estimate.	HA		08.12.98	08.26.98
AA08.12.98.01	Revise and submit site drainage (*added collection points*) for revised commissary roof drainage *(in Pricing Documents)* and *sanitary (not changed) Received commissary plan. Storm drain info to HA by 09.16.98 for completion by 09.23.98 (10.07.98).*	CHPA/HA	2 7 2	08.19.98 09.23.98 10.07.98	10.21.98
AA08.12.98.02	Update site estimate.	HA		08.26.98	08.26.98
AA08.12.98.03	Revise and submit site plan to reflect commissary, *and its impact on site - truck entry, loading area, trash containers, etc.*	HA/ELS/CHPA/NS		08.19.98	08.26.98
AA08.12.98.04	Design lighting operation/wiring for Road D (IA08..26.98.03). *Sketch within one month by TEE. Needs current site plan.*	NS/HA/TEE		Issues Log	08.26.98
AA08.12.98.05	Traffic operational plan to be sent to HA.	NS		08.14.98	08.26.98
AA08.12.98.06	Resolve traffic/road design issues with Lone Star Park (IA07.01.98.01).	NS/HA			08.12.98
AA08.12.98.07	Complete right-of-way abandonment (IA07.01.98.10).	NS/HA		08.18.98 09.01.98	08.12.98
AA08.12.98.08	Complete district land trade (IA07.01.98.11).	NS/HA		09.01.98	08.12.98
AA08.12.98.09	Review of documents/Final Plat for improvement dedication to City. (IA07.15.98.04)	NS/HA			08.12.98
AA08.12.98.10	Rethink overflow drain vs. scuppers for roof drainage. (Related item AD08.12.98.01)	ELS/CHPA		08.26.98	08.26.98
AA08.12.98.11	Resolve traffic analysis outstanding items, i.e. access route to new commissary prior to planning and zoning hearing. Prepare related explanatory drawing. *Director of planning confirmed that there was no need to revise & resubmit*.	HA		08.14.98	08.26.98
AA08.12.98.12	Present revised site plan at Planning & Zoning hearing.	NS/HA		08.19.98	08.26.98
AA08.26.98.01	Provide LCC with a full set of documents HA used to prepare estimate.	HA		08.26.98	
AA08.26.98.02	Decision on sign *size and* location metes and bounds to support easement documents.	NS/HA/ELS	1	08.26.98 09.23.98	09.23.98
AA08.26.98.03	Decision on date for City Council meeting/approval, 09.02.98 (IA07.01.98.08).	NS		08.28.98	
AA08.26.98.04	Contact R.Cox,Texas Utilities about coordinating base CAD file.	HA		08.31.98	
AA08.26.98.05	Contact R.Cox, Texas Utilties about service provisions and Texas Utilities participation.	NS		08.31.98	
AA08.26.98.06	Resolve pavement thickness design prior to the City Council hearing.	HA		09.01.98	

AA08.26.98.07	Prepare an exploration plan for borrow material evaluation and comparison.	HA		09.09.98	
AA08.26.98.08	Contact TAS/Barrier Free Texas to initiate early review and resolve the filing and approval process *(BFT completerd early review with comments. Filing can be in 2 or more packages)*.	ELS		09.09.98	
AA08.26.98.09	Cost-Benefit analysis both light poles and various schemes.	HA/TEE		09.09.98	
AA08.26.98.10	Second set of overflow roof drains connect to main system. To be confirmed by Grand Prairie.	ELS/CHPA		09.09.98	
AA08.26.98.11	Texas Utilities acceptance of current configuration of electrical yard (AA09.09.98.11).	FE	2	09.09.98 10.07.98	Combined Below
AA09.09.98.01	TAS Accessibility Specialist review to be complete prior to TAS filing (IA07.15.98.02).	ELS		09.09.98	09.09.98
AA09.09.98.02	Organize TAS submittal documents for internal and external review (IA07.15.98.03).	HA/ELS		09.09.98	09.09.98
AA09.09.98.03	Define Lighting for site, including fixture type and configuration/spacing to match Lone Star Park where feasible (IA08.12.98.01).	HA/ELS/NS/ TEE		09.09.98	09.09.98
AA09.09.98.04	Confirm LCC estimate such that utilizing 55 foot poles (13) for the parking lot lighting, each with 3-1000 watt fixtures, at 300 feet o.c. will result in a net cost savings of $15,000 over 40 foot poles (38) with 1-1000 watt fixture.	FE/LCC		09.23.98	09.23.98
AA09.09.98.05	Determine the most effective design/cost solution to provide overflow roof drainage. (AD10.07.98.01)	CHPA/ELS/ LCC	2	09.23.98 10.07.98	To MEPF
AA09.09.98.06	Discuss the overflow roof drain situation with City of Grand Prairie and attempt to negotiate dual system.	NS		09.23.98	09.23.98
AA09.09.98.07	Revise off-site civil design to delete right turn lane from Beltline Road and add a right turn lane on Lonestar Pkwy where it turns onto Beltline Road, per the City's request.	HA		09.23.98	09.23.98
AA09.09.98.08	Results of testing program to obtain geotech information on borrow material. Drilling to commence 09.10.98.	HA		09.23.98	09.23.98
AA09.09.98.09	Based upon borrow material characteristics, make engineeering determination from 3 alternative pavement designs provided. *High PI of borrow material requires inport of select fill; choose pavement design based on select fill specification.*	HA	2 5 2	09.23.98 10.07.98 10.21.98 11.04.98	11.04.98
AA09.09.98.10	Obtain comparables on fill material for negotiation with LSP.	HA	5	09.23.98 10.23.98	10.21.98

AA09.09.98.11	*Upon Texas Utilities final design, and acceptance of current configuration of electrical yard (AA08.26.98.11)*;resolve the general electric service/scope of work with TU (loop service w/manual transfer switch). *Revised yard layout sent to TU. TU approved.*	FE/TEE	2 2 7 2	09.23.98 10.07.98 10.21.98 11.04.98 12.02.98	12.02.98
AA09.09.98.12	*Upon final design by Texas Utitlities*, determine/coordinate location of easements.	HA	2	09.23.98 10.07.98	10.07.98
AA09.09.98.13	Determine location of handicap parking relative to main entrance doors; determine if side doors will be handicap accessible doors for either egress or ingress.	ELS/HA		09.23.98	09.23.98
AA09.09.98.14	Complete study and adjustment of civil list of cost increases.	HA/NS/LCC		09.23.98	09.23.98
AA09.23.98.01	Approval of assistance package by Grand Prairie City Council.	NS/HA		09.23.98	09.23.98
AA09.23.98.02	Followup overflow drain issues with Sharon Cherry, Building Official, City of Grand Prairie. (AD10.07.98.01)	CHPA		10.07.98	To MEPF
AA09.23.98.03	Confirm depths of 55 foot light pole bases and added cost to finalize decision to use over 38 foot poles.	TEE		10.07.98	10.07.98
AA09.23.98.04	Relocate handicap parking and revise related site grading.	HA		10.07.98	09.25.98
AA10.07.98.01	Prepare documents/Life Safety Issues for initial TAS review submission (IA07.29.98.02).	ELS		10.07.98	10.07.98
AA10.07.98.02	For city requested right hand turn lane from Beltline Road to Lone Star Parkway, send sketch/metes & bounds to City Comptroller/Sports Facilities Development Corp., A. Cammerata, to make aware of need.	HA		10.07.98	10.07.98
AA10.07.98.03	Review and comment on draft Life Safety document prior to initial TAS review submission.	NS		10.09.98	10.21.98
AA10.07.98.04	Send sketch to Texas Utilities for new location of on-site pad mouinted equipment *(switchgear location, pad sizes)*.	TEE/FE		10.14.98	To MEPF 10.21.98
AA10.07.98.05	Complete revised floor plan background upon which to revise underground/underslab utilities/structure.	ELS		10.16.98	10.21.98
AA10.21.98.01	Follow up borrow material availability and cost from Grand Prairie ISD. Should be less than $1/CY (IA10.07.98.01).	NS/HA		10.21.98	10.21.98
AA10.21.98.02	Complete paving estimate.	HA		10.23.98	11.04.98
AA10.21.98.03	Resolve requirements of joint use of single utility trench. *Info sent to TEE.*	FE	5	11.04.98 12.02.98	12.02.98
AA10.21.98.04	Request for Letter from Texas Utilities memorializing service and their agreed upon responsibilities.	NS	7 7	11.04.98 12.16.98	12.02.98

AA10.21.98.05	Sketch of transformer enclosure louvers to Texas Utilities. *No longer necessary due to approval of AA09.09.98.11.*	ELS	7	11.04.98 12.02.98	12.02.98
AA10.21.98.06	Decide location of Gas Meter. *Location decided by CHPA plan; not yet approved by TU*	HA/TEE/ ELS	5	11.04.98 12.04.98	12.02.98
AA10.21.98.07	*Closing occurred 11.02.98*; Final Plat *utility signatures to be obtained* and recorded. *Half completed.*	HA	2 5	11.04.98 12.16.98	12.02.98
AA11.04.98.01	Complete City land trade; complete land transfer with City Comptroller/Sports Facilities Development Corp (IA10.21.98.02).	NS/HA		11.04.98	11.04.98
AA11.04.98.01	Negotiate with Kaminsky,LSRP (and, later, GPISD), to purchase common fill borrow material, 30,000 cuyd at $0.75/cuyd in place (IA09.09.98.01); look for sand in Kaminsky material.	NS/HA	7	12.02.98	12.16.98
AA12.02.98.01	Texas Utilities approval of gas meter location.	HA		12.16.98	
AA12.02.98.02	Revise site sanitary and storm connection points to accomodate changes in the mechanical/plumbing plan ($10,000 est.added cost); alternatively, run lines internal to the building.	HA/CHPA		12.16.98	
AA12.02.98.03	Resolve proposed program changes to add special events power and water to parking lot.	NS/ELS/CH PA/HA		12.16.98	
AA12.02.98.04	Decide early construction program.	NS/ELS/HA		12.16.98	
AA12.02.98.05	Decide contracting format for sitework (Gen Cond, Supplmntl, Conditions of Contract) (IA11.04.98.01).	NS/HA/LCC		12.16.98	
AA12.02.98.06	Send copy of Engineering Joint Council documents.	HA		12.16.98	
AA12.02.98.07	Revise grade change at side of commisary.	HA		12.16.98	
AA12.02.98.08	Landscape not yet released by NS; use HA budget for pricing.	HA		12.16.98	

__B. Structural__

AB09.09.98.01	Complete 3-D model with member sizes and down load to SPI (IB08.26.98.01). Compete with column sizes; correct download errors..	HW	5	09.23.98 10.02.98	09.23.98
AB07.01.98.01	• Provide/fax structural tables for beam sizes/spacing to ELS.	HW		07.02.98	07.02.98
AB07.01.98.02	Resolve balcony *structural design* and sight lines; *requires seating envelope/platform to be resolved.*	ELS/HW	1	07.28.98 08.12.98	08.12.98
AB07.01.98.03	Revised *low* roof slopes required by HW for structural design.	ELS		07.28.98	07.28.98
AB07.01.98.04	Provide elevator shaft dimensions and	ELS		07.07.98	07.13.98

	structural loads to HW.				
AB07.01.98.05	Provide preliminary chase locations and sizes to HW.	ELS/CHP A	7	07.07.98 08.12.98	08.12.98
AB07.01.98.06	Resolve roof loading from hung structural platform, scaffolding live load, and acoustical panels.	ELS/HW/ JHSA	7	07.07.98 *07.28.98*	07.28.98
AB07.01.98.07	Resolve seating platform design, elevations, and structural load; *geometry, sight lines refinement based upon revised seat.*	ELS/HW	2	07.07.98 08.05.98	08.12.98
AB07.01.98.08	Provide/confirm *location* and structural loads *(confirm)* of electrical equipment to HW *(greater than 500 lbs).*	TEE	7	07.14.98 08.12.98	08.12.98
AB07.01.98.09	Provide location and structural loads for theatrical rigging system to HW. *Also, point loads for proscenium reduction system. Geometry of loading is critical. Set for 3-D model.*	TS/*AA*		07.14.98 08.26.98	08.26.98
AB07.01.98.10	Provide/confirm location and structural loads of speakers/audio equipment to HW.	JHSA		07.14.98	07.29.98
AB07.01.98.11	Provide/confirm location, electrical load, and structural loads of lighting *projectors at* balcony to HW/TEE.	AA		07.14.98	07.29.98
AB07.01.98.12	Provide/confirm location and structural loads of audience/house and proscenium reduction systems to HW.	AA		07.14.98	07.29.98
AB07.01.98.13	Confirm receipt of CHPA drawings indicating duct and pipe locations and loads, including proscenium deluge system.	HW		07.14.98	07.29.98
AB07.01.98.14	Provide *fi*nal results of wind tunnel test.	ELS/HW	5	07.14.98 08.12.98	08.12.98
AB07.15.98.01	Resolve alternative balcony beam sizes and spacing options; integrate with the 3D model.	HW/ELS	5	07.24.98	07.29.98
AB07.15.98.02	Resolve design wind forces/pressures on the building.	HW	5	07.24.98 08.12.98	08.12.98
AB07.15.98.03	Prepare 90 day structural steel commitment and expenditure schedule, include options for millrun steel and warehouse steel.	HSC	3	07.28.98 08.26.98	08.26.98
AB07.29.98.01	Resolve concessionaire reprogramming effect on back of house low roof. *ELS package rec'd last week, based on Scheme 'A'.*	NS/ELS/VS		08.05.98 08.26.98	08.26.98
AB07.29.98.02	Determine effect of delaying 3D model to 09.16.98 on project schedule, *i.e. fabrication/detailing.*	HW/HSC/LC C		08.12.98 08.26.98	08.26.98
AB07.29.98.03	Decision required to maintain construction start date and approve structural steel order for mill run steel and fab shop commitment without 3D Model(IB07.15.98.02).	NS		08.12.98	08.12.98
AB07.29.98.04	Complete new background drawings for back of house.	ELS		08.12.98 08.26.98	08.26.98
AB07.29.98.05	Provide all input to HW for structural detail of	ELS		08.12.98	08.12.98

	platform levels.				
AB08.12.98.01	Review schedule of four weeks for steel fabrication. (IB07.15.98.03) (AD08.12.98.05)	ELS		ASAP	08.12.98
AB08.12.98.02	Offline conference regarding utilizing 'Total Station' to do computerized field layout.	NS/LCC/ELS/ HW		08.26.98	08.26.98
AB08.26.98.01	Provide HW structural loads for box boom alternate locations.	JHSA/AA /ELS	2	09.01.98 09.23.98	09.23.98
AB08.26.98.02	Verify that box boom alternate locations hit 4000# support points.	JHSA/AA /ELS/ HW	2	09.01.98 09.23.98	09.23.98
AB08.26.98.03	Confirm assumptions for proscenium loads. *Provide sliding panel information. Major loads resolved and will be faxed.*	AA/ELS/ HW	2	09.04.98 09.23.98	09.23.98
AB08.26.98.04	Provide preliminary review of 3-D model to HSC/SPI/PB for review of connections and heavy steel members(IB07.01.98.01).	HW		09.04.98	09.09.98
AB08.26.98.05	Review value stream based on mill order steel *to determine order lead time*.	HSC/LCC		09.04.98	09.09.98
AB08.26.98.06	Coordination meeting *upon completion of 3D model* to finalize effect of stage and grid on structure. *(IB08.26.98.02)*	JHSA/AA/ELS/ HW/LCC		Issues Log	09.09.98
AB08.26.98.07	Define/*rev*iew the structural detailing in a coordination meeting to develop the sequence/schedule to serve the shop drawing/fabrication schedule.	HW/HSC/SPI/ PB/LCC		09.09.98	09.09.98
AB09.09.98.01	Complete 3-D model with member sizes and down load to SPI (IB08.26.98.01). Compete with column sizes; correct download errors.	HW	5	09.23.98 10.02.98	09.23.98
AB09.09.98.02	Meeting @ HW on Monday 9/14/98 @ 1:30 p.m. to determine detailing input sequence needed by HW & SPI to accommodate fabrication schedule shown in 21 month value stream.	HW/HSC/SPI/ LCC/PB		09.14.98	09.23.98
AB09.09.98.03	Finalize wall design/acoustics for F.O.H. mechanical rooms. *CHPA to confirm AHUs/configuration to mitigate wall acoustics; also, alternative wall designs.*	JHSA/ELS/ CHPA	2	09.23.98 10.07.98	10.07.98
AB09.09.98.04	Review HW 3D model data transmission for system compatibility.	HS/SPI		09.23.98	09.23.98
AB09.23.98.01	Schedule work session upon completion of 3D model with structural and theatrical consultants to address issues and detailing of stage house and auditorium roof. *Coordination meetings set for 09.29.98 and 09.30.98. (Formerly AB08.26.98.06) (IB08.26.98.02).*	NS/ELS/HW/ HSC/PB/JHSA/ CHPA/TEE/ AA/TSC/SPL/ PA		09.30.98	09.23.98
AB09.23.98.02	Review design/structural implications of alternate interior wall systems requiring acoustical consideration.	JHSA/HW/ELS		10.07.98	10.07.98

AB10.07.98.01	Develop/detail steel platform design for curved seating format, including curved and slotted riser, and installation of riser mounted seating (involve Irwin Seating). Draw section for each typical riser height.	ELS/HW/MBS /AA/LCC		10.09.98	10.21.98
AB10.07.98.02	Revise structure to reflect development of the fly tower and rigging wall. Provide rigging wall section.	HW/ELS/ AA	2	10.09.98 11.04.98	11.04.98
AB10.07.98.03	Coordination meeting with CC regarding purlin framing, wall sections, and wind girts (locations relative to interior finishes); fabrication and installation responsibility. Provide plan and wall section.	HW/ELS		10.15.98	10.21.98
AB10.07.98.04	Revise framing to accommodate concrete under roof top units at BOH, *top of offices*.	HW/ELS	5	10.21.98 11.02.98	11.04.98
AB10.21.98.01	Identify allowable deflection for purlins supporting interior finishes.	HW		11.04.98	11.04.98
AB10.21.98.02	Resolve purlin design with regard to interior finishes.	HW/ELS/CC		11.04.98	11.04.98
AB10.21.98.03	Review riser design with regard to platform construction.	MBS		11.04.98	11.04.98
AB10.21.98.04	Establish overall general design for seating risers. *Resolve concept design reviewed with MBSI.*	HW	1 2	11.04.98 12.16.98	12.02.98
AB10.21.98.05	Complete seating platform design to be able to complete 3D Model download by *12.11.98* (and ABM by *12.18.98*) (IB07.15.98.01). *Havens currently doing hand take-off for costing.*	ELS	2 5	11.06.98	12.02.98
AB10.21.98.06	Resolve retaining wall location which has been influenced by the seating platform curve.	ELS/HW/ PB/ LCC	7 7	11.04.98 12.16.98	12.02.98
AB10.21.98.07	Review four seating mounting details with Irwin Seating.	ELS		11.04.98	11.04.98
AB10.21.98.08	Resolve the structural support and acoustical requirements at "meet and greet" areas at west side of building; *HVAC Units moved*.	ELS/HW/JHSA		11.04.98	11.04.98
AB10.21.98.09	Revisit/update steel detailing value stream sequences to decide how far to proceed.	HW/HS/SPI/ LCC		11.04.98	11.04.98
AB11.04.98.01	Revise 3-D Model to reflect curved seating format (IB10.07.98.01).	HW		11.04.98	11.04.98
AB12.02.98.01	Review prefab stair utilization (IC08.12.98.02, IB08.12.98.01). Specifications allow the use of prefab stairs at specific locations.	ELS		12.02.98	12.02.98
AB12.02.98.02	Resolve pricing set coordination issues, i.e. column locations, to be able to complete 3D Model.	ELS/HW		12.16.98	
AB12.02.98.03	HW/PB meeting on 12.03.98 to review erection sequence on which ABM's are based.	HW/PB		12.16.98	

AB12.02.98.04	Resolve proposed changes relative to 3D Model, i.e. stage house.	NS/ELS/HW		12.16.98	

C. Enclosure/Architectural

AC07.15.98.02	Resolve insulation requirements for shell of the building. *Refine energy calculations for specific R value for walls and roof (IC07.01.98.01). Sound/Power ratings of cooling towers will drive amount of insulation or dbl sheet rock.*	ELS/JHSA/ CHPA		07.28.98 08.18.98	08.26.98
AC07.29.98.01	Prepare life safety narrative outline.	ELS		08.12.98	08.06.98
AC08.12.98.01	Evaluate status of input for structural detailing. *Value stream.*	HW		08.26.98	08.26.98
AC08.12.98.02	Determine 'R' value for roof considering both thermal insulation and noise. (IC07.15.98.01) (DC08.12.98.01)	ELS/JHSA/ CHPA		08.12.98	08.12.98
AC07.15.98.01	Complete louver selection (IC07.01.98.04).	ELS/CC		07.22.98	07.29.98
AC07.15.98.03	Resolve material selection at the building base.	ELS/LCC		Issues Log	07.29.98
AC08.12.98.03	Complete roof and wall input concept drawings. (IC07.01.98.02) *Wal designs should be complete before roof design begins, and roof drawings will take about ten days after that. Scuppers are not an issue.*	ELS/CHPA		08.25.98	08.26.98
AC08.26.98.01	Provide metal samples of color and finish for selection *(deleting 'and exterior mock ups'); two of three received.*	CC/ELS	5	09.09.98 10.07.98	10.07.98
AC08.26.98.02	Clearly identify on the concept drawings the location of each color, and determine quantity of each of the vertical, horizontal and smooth panels so the cost for custom colors for each type can be assessed.	ELS/CC		09.09.98	09.09.98
AC09.09.98.01	ELS issuance of *exterior* glass and stair design package to CC (IC07.01.98.03).	ELS		09.17.98	09.23.98
AC09.09.98.02	ELS to detail the desired exterior wall mock-up and proposed location at the site (IC08.26.98.01).	ELS	4	09.23.98 09.30.98	10.07.98
AC09.09.98.03	Determine metal panel custom colors based on ELS submitted color chips and quantities for each of the colors.	CC/ELS	2	10.07.98	10.07.98
AC09.09.98.04	Determine metal panel custom colors premium cost based on economic order quantities.	ELS/CC	2	10.07.98	10.07.98
AC09.09.98.05	Determine if roof valley lines to drain locations can be accomplished with concrete rather than being built up by PC.	ELS/HW		09.23.98	09.23.98
AC09.23.98.01	Confirm concrete wall and roof deck at back of house low area.	ELS		10.07.98	10.07.98
AC10.07.98.01	Revise exterior wall mock-up detail; propose	ELS		10.21.98	10.21.98

	site location.				
AC10.07.98.02	Provide drawing of alternate value engineered BOH metal panels; reduced parapet height.	ELS		10.21.98	10.21.98
AC10.07.98.03	Resolve number of layers of gypsum board as alternative to CMU to achieve accoustical objective - Vomitory, etc. *To be included in Pricing Documents.*	ELSJHSA	2	10.21.98 11.06.98	11.04.98
AC10.21.98.01	Provide enclosure mock-up pricing.	LCC/CC	5	11.13.98	12.02.98
AC10.21.98.02	Coordinate interior finish support (interior studs and drywall) with high wall metal panel suport girts.	HW/CC/ELS		11.04.98	11.04.98
AC10.21.98.03	Identify roofing material for each roofing section, esp. low canopy roof visible from lobby balcony - *aggregate/paver roofscape*; provide pricing *and samples*.	ELS/LCC /PC	7 6	11.04.98	12.02.98 12.16.98
AC11.04.98.01	Resolve mock-up schedule: 2 months to fabricate panels; *2 months* to erect mock-up, make changes, and make decision (3 months to fabricate building panels; 120 to 150 day building critical path).	ELS/LCC /CC/ NS	1	12.02.98	12.16.98
AC11.04.98.02	Resolve door acoustical ratings. *Will not have ratings.*	ELS/JHSA		12.02.98	12.02.98
AC12.02.98.01	Determine if a mock-up(s) of exterior wall will be required; to be price based. *Ordering, fabricating, erecting, and making decisions based upon the mock-up are critical path tasks (IC09.09.98.01).*	NS		12.07.98	
D. Mechanical/Electrical/Plumbing/Fire Protection					
AD07.01.98.01	Post Drawings on FTP site.	CHPA	3	07.06.98 08.12.98	08.12.98
AD07.01.98.02	Provide/confirm audio system power requirements to TEE.	JHSA		07.07.98	07.07.98
AD07.01.98.03	Provide/confirm audio system cooling requirements to CHPA.	JHSA		07.07.98	07.07.98
AD07.01.98.04	Provide/confirm emergency power items to TEE/CHPA.	ELS		07.08.98	07.14.98
AD07.01.98.05	Provide/confirm normal and emergency loads to TEE.	CHPA	7	07.08.98 07.30.98	07.30.98
AD07.01.98.06	Provide/confirm architectural/theatrical lighting and video power loads to TEE/CHPA.	AA		07.08.98	07.08.98
AD07.01.98.07	Resolve location of main electrical room (162) and electronics storage and shop (158) to facilitate piping from cooling tower. LCC to provide pricing input. Not applicable due to commissary design change.	ELS/TEE/ CHPA/*LCC*	5	07.08.98 08.12.98	08.12.98
AD07.01.98.08	Provide pipe/duct weights to HW	CHPA		07.14.98	07.14.98

AD07.01.98.09	Provide concession/food service electrical loads to TEE/*CHPA. Revise food service loads due to program change. Note: Concession charts were received and show equipment loads and revised floor plan raise the cost from the current estimate.*	NS/ELS		07.08.98 08.26.98	08.26.98
AD07.01.98.10	Provide CATV and Data information to TEE.	NS/JHSA/AA		Issues Log	07.29.98
AD07.01.98.11	Provide elevator electrical loads/data to TEE.	ELS/LCC		07.08.98	07.08.98
AD07.01.98.12	Provide life safety *[and exit sign loads]* (Rolf Jensen Assoc.) to TEE.	ELS		07.08.98	07.29.98
AD07.01.98.13	Provide/confirm location of raceway loads to HW/TEE/CHPA.	AA/JHSA	5	07.14.98 08.12.98	08.12.98
AD07.01.98.14	Provide transformer sizes to TEE.	AA/JHSA		07.14.98	07.14.98
AD07.01.98.15	Provide/confirm general lighting loads to CHPA.	TEE		07.14.98	07.14.98
AD07.01.98.16	Provide emergency power motor sizes to TEE.	CHPA		07.14.98	07.14.98
AD07.01.98.17	Provide fire pump information to TEE.	WSFP		07.14.98	07.14.98
AD07.01.98.18	Provide concession/food service layout information (Volume Services). Big picture matrix: 3000 SF	NS/ELS	2	07.14.98 07.31.98	08.12.98
AD07.01.98.19	Air zones approval; *block out areas served by AHU's for review* (zones of operation; zones for control, ID07.01.98.02).	NS/CHPA/MMC/ELS	7	07.14.98 07.30.98	08.12.98
AD07.15.98.01	Confirm subcontractor participation in evaluating on-line project management approach.	FE		07.22.98	07.22.98
AD07.15.98.02	Resolve sheet metal duct work design; provide to JHSA for approval.	CHPA/LL	7	07.20.98 07.31.98	08.12.98
AD07.15.98.03	Provide feedback/approval of sheet metal ductwork design to ELS (ID07.01.98.01).	JHSA	2	07.22.98 08.03.98	08.12.98
AD07.15.98.04	Provide lobby lighting loads to ELS.	TEE/AA		07.22.98	07.22.98
AD07.15.98.05	Meet with cablevision to explore infrastructure requirements for in-house television system.	NS		Thtrcl/Int	07.29.98
AD07.15.98.06	Lighting operations approval; block out areas served by lighting - zones of operation/control (IE07.01.98.02).	TEE/AA		07.28.98	07.28.98
AD07.15.98.07	Coordinate location of proscenium deluge system with other systems.	WSFP/HW/CHPA/AA	6	07.28.98 08.05.98	08.12.98
AD07.29.98.01	Follow up proscenium deluge system meeting - operation, pipe size, curtain physical make-up. (ID08.12.98.04)	WSFP/HW/CHPA/AA/LCC/ELS	2	Issues Log	08.12.98
AD07.29.98.02	Follow up acoustics meeting after JHSA reviews sheetmetal design. (ID08.12.98.02)	JHSA/ELS/CHPA/LC	2	Issues Log	08.12.98

		C			
AD07.29.98.03	Resolve safety requirements for proscenium deluge system with Rolf Jensen. (ID08.12.98.03)	WSFP/CHPA/AA/LCC	2	Issues Log	08.12.98
AD07.29.98.04	Resolve supply duct routing from house to mechanical chase/AHU. Reworded as: House duct route and outlet locations move to follow new architectural layout. (ID08.12.98.04)	CHPA/JHSA/ELS/LCC	2	Issues Log	08.12.98
AD07.29.98.05	Resolve additional MEPF requirements for adding commissary kitchen.	CHPA/TEE WSFP/FE/LCC		08.05.98 08.26.98	08.26.98
AD07.29.98.06	Resolve additional requirements for addition/revision to suite level toilet rooms. *Add to floor plan.*	CHPA/TEE ELS/LCC		08.05.98 08.26.98	08.26.98
AD07.29.98.07	Coordinate ceiling acoustical panels and house air outlets. Now combines with AD07.29.98.04 above, becoming ID08.12.98.04.	CHPA/JHSA / ELS/LCC		Issues Log	08.12.98
AD07.29.98.08	Add acoustics value stream into project value stream. (ID08.12.98.05)	JHSA/LCC		Issues Log	08.12.98
AD07.29.98.09	Meet onsite with Texas Utilities to permanent and temporary electric service.	TEE/ELS/HA/FE/LCC/NS		08.12.98 08.19.98	08.26.98
AD08.12.98.01	Resolve roof drainage design to complete enclosure package. (Related item AA08.12.98.10)	CHPA/ELS		08.25/98	08.26.98
AD08.12.98.02	Determine ASHRAE design temperatures. Consider adjusting D/FW design standards due to temperature change condition.	NS		08.19.98	08.26.98
AD08.12.98.03	Verify exact locations on marked plan to be designated 'smoking areas'.	NS		08.19.98 09.09.98	09.09.98
AD08.12.98.04	Determine effect of *suite* smoking areas on mechanical system.	CHPA	2	09.09.98 09.16.98	09.23.98
AD08.12.98.05	Reconfigure ductwork at *auditorium* hard ceiling for JHSA/ELS review.	CHPA/MMC/LL/LCC	5	08.26.98 09.10.98	09.23.98
AD08.12.98.06	Team to test assumptions for delivery duct layouts in complying with acoustic requirements. *Note: Revised duct plans will be available by 4 Sept. 98. Drawings to JHSA 09.10.98.*	CHPA/MCC/LL/LCC	2	08.26.98 09.17.98	09.23.98
AD08.12.98.07	Prepare summary list of electrical load requirements for presentation to Texas Utilities.	TEE		08.19.98	08.26.98
AD08.26.98.01	Determine roof drain pipe routing and resolve potential pipe and roof drain locations conflicts.	CHPA	5	09.09.98	10.07.98
AD08.26.98.02	Confirm roof drainage overflow design with Grand Prairie.	CHPA		09.09.98	09.09.98

AD08.26.98.03	Follow up proscenium deluge system meeting - operation, pipe size, curtain physical make-up (AD07.29.98.01 & AD07.29.98.07) (ID08.12.98.01).	WSFP/HW/ CHPA/AA/LCC/ELS	2	09.09.98 Move to Theatrical	09.09.98
AD08.26.98.04	Obtain sound/power ratings and provide to JHSA. *Waiting on Cook Fan ratings.*	CHPA/MMC	2	09.09.98 09.16.98	09.23.98
AD08.26.98.05	Provide *concept* equipment layout for food service areas. *Detailed design upon vendor selection.*	NS/CI	7	09.09.98 09.23.98	09.23.98
AD08.26.98.06	Determine increased power requirements for food service areas.	NS/CI/TEE		09.09.98	09.09.98
AD09.09.98.01	House duct route and outlet locations move to follow new architectural layout (AD07.29.98.04, ID08.12.98.04).	CHPA/JHSA / ELS/LCC		09.09.98	09.09.98
AD09.09.98.02	Determine routing/enclosure of exterior duct at front of house (ID08.26.98.02).	CHPA		09.09.98	09.09.98
AD09.09.98.03	Review implications of two-hour house/lobby separation vs 21,000 cfm lobby smoke exhaust *(selected)*, life safety and cost.	ELS/CHPA/ LCC		09.09.98 09.23.98	09.23.98
AD09.09.98.04	Provide per Texas barrier-free access, a unisex single toilet for each grouping of mens and womans toilets.	ELS		09.09.98 09.23.98	09.23.98
AD09.09.98.05	Provide building infrastructure requirements for CATV, theatrical, and Data information to TEE. Identify the spaces within the building; 09.29/30.98 Meeting (ID07.01.98.10).	NS/JHSA/AA		09.23.98	09.23.98
AD09.09.98.06	Follow up acoustics meeting after JHSA reviews sheetmetal design (AD07.29.98.02, ID08.12.98.04, ID08.12.98.02).	JHSA/ELS/ CHPA/LCC		09.23.98	09.23.98
AD09.09.98.07	Coordinate duct sizing and delivery design options.	CHPA/LL		09.23.98	09.23.98
AD09.09.98.08	Review acoustical requirements for mech. equipment wall systems, *central plant* (formerly AC09.09.98.06) From E/A 09.23.98	ELS/JHSA	5	09.23.98	10.07.98
AD09.09.98.09	Front Mech.Room: CMU walls may be needed acoustically; currently metal studs/drywall;may require heavier walls (8" block w/2 layers gypsum) or change in building envelope enlarging mech.room (formerly AC09.09.98.07);JHSA sketch to HW.From E/A 09.23.98	ELS/JHSA	2	09.23.98	10.07.98
AD09.23.98.01	Provide data for small ahu/fan coil unit in basement mechanical equipment room.	CHPA		09.30.98	10.07.98
AD09.23.98.02	Provide TEE/FE scope of design as a basis for preconstruction letter agrement and projected cash flow.	TEE		10.07.98	10.07.98
AD09.23.98.03	Confirm/revise layout of electrical room and electrical yard.	TEE		10.07.98	10.07.98

AD09.23.98.04	Provide for *4* to *6* food service exhaust duct fans and returns in lobby area (original program included 2 to 3). Provide location of kitchen supply fans(AD10.07.98.04). Holding for concession consultant equipment concept.	CHPA/CI/ ELS MMC/LL	1 1 2	10.07.98 12.01.98	10.21.98
AD10.07.98.01	Determine effect of concession smoking areas on mechanical systems. (ID09.23.01)	CHPA		10.07.98	From S/C 10.07.98
AD10.07.98.02	Determine the most effective design/cost solution to provide overflow roof drainage. Followup overflow drain issues with Sharon Cherry, Building Official, City of Grand Prairie (AA09.09.98.05 & AA09.23.98.02). Provide sketch/documentation to GP.	CHPA	2 5 7	09.23.98 10.07.98 10.14.98 11.04.98	From S/C 10.07.98 11.04.98
AD10.07.98.03	Provide revised AHU layout at FOH mechanical rooms.	CHPA		10.21.98	10.21.98
AD10.07.98.04	Meet with cablevision to explore infrastructure requirements/*formats* for in-house *live broadcast and closed circuit* television system (AD07.15.98.05). *Identify options/design responsibility/proposal/scope of work.*	NS	#	08.07.98 09.23.98	09.23.98
AD10.07.98.05	Revise Food Service/Commissary program including upper level food service capabilities (IE07.01.98.01). (Scheme B received from ELS during the meeting.)	NS/VS/ELS		08.05.98 08.26.98	08.26.98
AD10.07.98.06	Revise Suite Level toilet room program/design. NextStage to review layouts.	NS/CHPA/E LS		08.05.98 08.26.98	08.26.98
AD10.07.98.08	Develop commissary utility metering level.	NS/CII		08.14.98	08.26.98
AD10.07.98.09	Confirm that structural engineers have theatrical dimming rack and Audio amplifier rack loads.	JHS/SP	7	08.14.98 09.23.98	09.10.98
AD10.07.98.10	Clarify the conceptual design/layout in the concessions area relative to headroom condition.	ELS/CI	7	09.09.98 09.23.98	09.23.98
AD10.07.98.11	Define type and size of stage rear doors for framing input.	ELSl/AA		09.09.98	09.09.98
AD10.07.98.12	Finalize plan layout as a result of adding commissary.	ELS/NS		08.14.98	08.26.98
AD10.07.98.13	Provide location of kitchen supply fans.	CHPA	1	10.21.98 11.04.98	Combined Above
AD10.07.98.14	Revise roof drain design to reflect roof changes.	CHPA		10.21.98	10.21.98
AD10.07.98.15	Review commissary program and confirm food service exhaust duct fans and returns. *New concept.*	NS		10.21.98	10.21.98
AD10.07.98.16	Resolve need for fire pump; determine water pressure required at roof and proscenium.	CHPA/RJA/ WSFP/ELS		10.21.98	10.21.98
AD10.07.98.17	Confirm connection of fire pump with respect to main and emergency generator.	TEE/FE		10.21.98	10.21.98
AD10.07.98.18	Provide layout and size of BOH (rear) duct runs for acoustical analysis.	CHPA/LL	2	10.21.98 11.04.98	11.04.98

AD10.07.98.19	Provide layout showing telephone, data, and CCTV locations to be serviced with empty conduit. *Provide CATV and data information to TEE (AD07.01.98.10/IE07.29.98.01).*	NS	5	10.21.98 10.28.98 11.04.98	11.04.98
AD10.07.98.20	Meet with telephone company to review the project. *Coordinate with NS. NS to negotiate costs.*	NS/ELS/ TEE/ *FE*	5 7	10.21.98 11.04.98 12.02.98	12.02.98
AD10.07.98.21	Review/confirm normal and emergency power loads. *Schedule requires updating.*	TEE	2 2	10.21.98 11.04.98 12.02.98	12.02.98
AD10.21.98.01	Send sketch to Texas Utilities for new location of on-site pad mounted equipment *(switchgear location, pad sizes)* (AA10.07.98.04). *Develop alternate options for TU consideration.*	TEE/FE	5 5	10.14.98 10.23.98 11.04.98	11.04.98
AD10.21.98.02	Provide latest mechanical unit layouts; verify weight and layout of new units.	CHPA		11.04.98	11.04.98
AD10.21.98.03	Review/mark-up underseat air slot bands.	CHPA		11.04.98	11.04.98
AD10.21.98.04	Completion of Electrical Pricing Documents, including complete underground/underslab electrical construction documents (ID10.07.98.03). *One line and recepticle/power drawings only submitted.*	TEE	5 5	11.09.98	11.16.98 12.16.98
AD10.21.98.05	Reconsider deluge system decision/design based upon Rolf Jensen Associates review. Deluge "A" included in pricing documents. *Alternate:"B" closely spaced sprinkler heads reacting individually;also, proscenium reduction system functions as a fire curtain.*	ELS/CHPA/ WSFP	2 1	11.04.98	12.02.98 12.16.98
AD11.04.98.01	Control of AHU noise as it travels down the duct path (ID10.07.98.01). *Base units changed.*	CHPA/JHSA		12.02.98	12.02.98
AD11.04.98.02	Outline options for acoustical consideration (ID10.07.98.02).	CHPA/JHSA		12.02.98	12.02.98
AD11.04.98.03	Followup overflow drain issues with Sharon Cherry, Building Official, City of Grand Prairie. *Awaiting return response.*	CHPA	2	12.02.98	12.16.98
AD11.04.98.04	Provide gas meter information - size, clearance.	TSPH/CHPA	5	12.02.98	12.16.98
AD11.04.98.05	Based upon consessionaire design provide gas requirements for cook areas.	CHPA	2	12.02.98	12.16.98
AD11.04.98.06	Resolve generator requirements.	CHPA/TEE		12.02.98	12.02.98
AD11.04.98.07	Confirm assumptions regarding lighting controls (ID12.02.98.01).	CHPA/TEE		12.02.98	Issues Log 12.02.98
AD12.02.98.01	Decision regarding code/security acceptance of open yard flexibility w/o having separations between electrical switch gear, cooling tower, etc.	FE		12.16.98	
AD12.02.98.02	Provide Electrical Specifications.	TEE		12.16.98	

E. Theatrical/Interiors

AE07.01.98.01	Send/fax theatrical event proforma to AA/JHSA.	NS		07.02.98	07.02.98
AE07.01.98.02	JHSA and SPL to meet to review audio concepts.	JHSA/SPL	7	07.07.98 08.12.98	08.12.98
AE07.01.98.03	AA and PAL to review theatrical lighting concepts.	AA/PAL		07.07.98	08.12.98
AE07.01.98.04	Confirmation of theatrical systems based on event proforma.	AA/PAL/JHSA /SPL		07.07.98	08.12.98
AE07.01.98.05	Confirm/*resolve* size of mid-house control position to ELS.	AA/JHSA/NS		07.07.98 08.12.98	08.26.98
AE07.01.98.06	Develop alternative audience/house reduction designs based upon new design parameters.	ELS/AA		07.10.98	08.12.98
AE07.15.98.01	Resolve house reduction system options (AF07.01.98.05). *Provide loads for both options to HW.*	NS	2	07.22.98 08.05.98	08.12.98
AE07.15.98.02	Resolve front lighting and vertical side box boom positions (*probably 2*). *Provide loads to HW*.	AA/PA	5	07.28.98 07.31.98	08.12.98
AE07.15.98.03	Resolve seat selection options; obtain chair samples and confirm dimensional envelope. (IE08.12.98.04)	NS/AA/ELS	5	Issues Log	08.12.98
AE09.09.98.01	Follow up proscenium deluge system meeting - operation, pipe size, curtain physical make-up: *Resolve curtain opaque surface.* (AD07.29.98.01 & AD07.29.98.07)(ID08.12.98.01) (IE09.23.98.01).	WSFP/HW/ CHPA/AA/ LCC/ELS	2	09.09.98 09.23.98	Issues Log 09.23.98
AE09.09.98.02	*Obtain chair samples and confirm within current seating envelope (AE07.15.98.03,IE08.12.98.04). NS to meet with ELS to make a decision on seating (IE08.12.98.01).* Review metal perforated vs. plastic bottom seats, and provide observations/ concerns to NS.	AA/JHSA /ELS/ LCC	5 5 6 1	09.23.98 10.07.98 10.21.98 11.04.98 12.02.98	12.02.98
AE09.09.98.03	Resolve life safety requirements for proscenium deluge system (wet fire curtain) with Rolf Jensen (AD07.29.98.03) (IE09.23.98.01).	ELS/CHP		09.23.98	Issues Log 09.23.98
AE09.09.98.04	Resolve alternate designs for mid-house control position. Row of removable seats in front.	AA/JHSA/NS/ ELS		09.23.98	09.23.98
AE09.09.98.05	Resolve structurally and operationally whether Box Booms will track or be fixed point loads. *Will be rigged.*	NS/AA/ELS		09.23.98	09.23.98
AE09.09.98.06	Determine effect of image magnification on walls and ceiling. *Provide 2-20 foot diameter screens; projector to be 30 feet out.*	AA/ELS		09.23.98	09.23.98

AE09.09.98.07	Prepare conceptual design for commissary and loading dock area, including trash compactor location.	CI/ELS		09.23.98	09.23.98
AE09.09.98.08	The commissary/loading dock changes need to be reflected on the ELS drawings, and provided to Creative Ind.	ELS	2	09.23.98	10.07.98
AE09.09.98.09	Submit Life Safety Program to Grand Prairie (IE08.12.98.05).	ELS		10.16.98	10.21.98
AE09.23.98.01	Provide layout sketch for *other equipment - electrical, ie. disconnects* - in the amplifier/*dimmer* rooms. Review size of amplifyer/dimmer room (AE10.21.98.01).	TEE	2 7	10.07.98 10.21.98 11.04.98	12.02.98
AE10.07.98.01	Resolve forestage rigging grid issue. *Confirm both structurals and 3-D model are based on 10' o.c., 4000# pt.lds; maximum gross tonnage, 3300#.* (IE08.12.98.03)	AA/JHSA		10.07.98	10.07.98
AE10.07.98.02	Determine the extent of theatrical lighting system that is necessary, *i.e. dimmer racks, etc.* to be provided as a part of the base building capital investment. NS developed description of essential equipment. (IE09.09.98.01)	ELS/AA AA/ELS/NS		10.07.98	10.07.98
AE10.07.98.03	Review proscenium deluge system:operation, *3in* pipe size, *volume*, curtain makeup: *Resolve life safety requirements,(wet fire curtain/curtain* opaque *surface) with Rolf Jensen.*(AD07.29.98.01 & AD07.29.98.07) (ID08.12.98.01)(AD07.29.98.07) (09.09.98.01/.03).	WSFP/HW/ CHPA/AA/ LCC/ELS		10.07.98	10.07.98
AE10.07.98.04	Forward acoustical testing reports from Irwin Seating to JHSA.	AA	7 7	10.14.98 10.21.98 11.04.98	11.04.98
AE10.07.98.05	Relocate Electrical room to opposite side of AV Room; identify size of AV Room; and, distribute for verification.	ELS		10.14.98	10.21.98
AE10.07.98.06	Provide revised auditorium backgrounds.	ELS		10.18.98	10.21.98
AE10.07.98.07	Provide systems plans for each level including wiring devices and conduit layout. (IE09.23.98.02)	AA/JHSA		10.21.98	10.21.98
AE10.07.98.08	Video//TV broadcast decision. (IE07.15.98.01)	NS/JHSA/A A		10.21.98	10.21.98
AE10.07.98.09	Resolve use of series of gratings instead of "no fall protection."	ELS/AA	2	10.21.98 11.04.98	11.04.98
AE10.07.98.10	Review combination of 3-seat sizes by section to arrive at a final seating plan; adjust aisles and vomitories *(Now Fixed)*. Irwin Seating to meet w/NS. *Irwin to do seat layout/count.*	ELS/AA	9	10.21.98 11.04.98 12.02.98	12.02.98
AE10.07.98.11	Obtain sample of Irwin metal pan perforated seat with curved lip. No differential envelope (IE12.02.98.01).	LCC	5 5	10.21.98 11.04.98 12.02.98	Issues Log 12/02.98

AE10.21.98.01	Review size of amplifyer/dimmer room.	ELS/AA/JHSA		11.04.98	See Above
AE10.21.98.02	Send new pit layout/dimensions to JHSA and AA for review (IE08.26.98.02).	ELS		10.28.98	11.04.98
AE10.21.98.03	Review/revise audience reduction system (IE10.07.98.02).	NS/ELS/AA		11.11.98	11.04.98
AE10.21.98.04	Review design program with NS independent producer/ reviewer, Peter Wexler. Ongoing.	ELS/AA/JHSA		12.02.98	12.02.98
AE10.21.98.05	Review proposed 3 reconfigurations and sizes for control booth/ FOH mixing position necessitated by radial seating change. Resolve constraints	AA/JHSA	2	11.04.98 12.02.98	12.02.98
AE11.04.98.01	Revisit discussion regarding height of grid above proscenium. Proscenium: Rock 50 FT, Broadway 32 FT Min. (IE10.07.98.03).	NS		11.04.98	11.04.98
AE12.02.98.01	Send copy of Production Arts Lighting GMP proposal to NS/ELS.	LCC		12.04.98	
AE12.02.98.02	Raise Stage House trim height from 80 Ft to 81Ft-3In by lightening stage house steel and adjustin roof pitch. Requires addding back rigging pit: 6Ft by 60Ft of basement space, per earlier drawing issue.	ELS/HW		12.16.98	
AE12.02.98.03	Send picture and dimensions of typical sound board to ELS, for selection of appropriate sized sissor lift.	JHSA		12.16.98	
AE12.02.98.04	Develop actual speaker locations/'look' of the proscenium; development meeting next week to generate describing graphics.	JHSA/SPL		12.16.98	
AE12.02.98.05	Colors and materials for lobby and house beign pulled by logo/ color development; colors and materials presentation after January 1st.	NS/ELS		01.11.98	
F. Project Support					
AF07.01.98.01	Approval of audio and theatrical lighting concepts.	NS		07.07.98	07.07.98
AF07.01.98.02	Issue project insurance memorandum for discussion.	LCC		07.07.98	07.07.98
AF07.01.98.03	Issue subcontractor preconstruction agreements for discussion, (IF08.26.98.01). *(Crown Corr agreement issued)*.	LCC		Issues Log	08.26.98
AF07.01.98.04	Resolve design agreement legal issues and complete ELS design agreement. *Effort continuing. Documents may not be filed for permits until legal issues are resolved and designers can be identified in the drawing title block (IF10.21.98.01).*	NS/ELS	5 5	07.10.98 10.21.98	Issues Log 10.21.98
AF07.01.98.05	Approval of audience/house reduction design solution.	NS		Thtrcl/Int	07.29.98

AF07.01.98.06	Identify potential national vendor partners. Effort continuing (IF08.26.98.02).	LCC/ELS		Issues Log	08.26.98
AF07.01.98.07	Identify project components not currently represented by team. Effort continuing.	LCC/ELS		Issues Log	08.26.98
AF07.01.98.08	Update and issue current project budget, as revised.	LCC		07.14.98	07.29.98
	Project Logs:				
AF07.01.98.09	• Develop a consistent format for project logs for review.	LCC		07.07.98	07.09.98
AF07.01.98.10	• Refine meeting action items, issue/maintain Action Items Log.	LCC		07.07.98	07.09.98
AF07.01.98.11	• Develop, issue and maintain Issues Log, and Decision Log.	LCC		07.10.98	07.09.98
AF07.01.98.12	Develop, issue and maintain Project Document Log.	ELS		07.14.98	07.29.98
AF07.01.98.13	• Approval of project logs and format.	NS		07.14.98	07.15.98
AF07.15.98.01	Amend log format to show Issue, Action Item, Decision trail; each item to have a discrete identity.	LCC/NS		07.29.98	07.29.98
AF07.15.98.02	Probability of construction start date - Status Report (IF08.26.98.03).	NS		Issues Log	08.26.98
AF07.15.98.03	Submit agreement for engineering *and other consultant* services (AF07.15.98.04).	NS/HA		Issues Log	08.26.98
AF07.15.98.04	Submit agreement for architectural services and other consultant design agreements.	ELS/HA		07.28.98	07.29.98
AF07.15.98.05	Resolve agreement with food service concessionaire.	NS		07.28.98	07.28.98
AF07.15.98.06	Revise estimate schedule for GMP.	NS/LCC		07.28.98	07.28.98
AF07.29.98.01	Prepare target cash flow estimate for both consultant design and subcontractor design efforts.	NS/ELS/LCC		08.12.98 08.26.98	09.09.98
AF07.29.98.02	Expand current summary project budget to detailed estimate (IF08.26.98.04)	LCC		Issues Log	08.26.98
AF07.29.98.03	Electronic communication of project information. Install project documents on communication web site server (IF07.15.98.06).	NC/ELS/ LCC	7	08.12.98 10.07.98	10.07.98
AF07.29.98.04	Include Food Service consultant, Creative Industries, in project progress meetings.	NS/LCC		08.12.98 08.26.98	08.12.98
AF07.29.98.05	Review and report on the status of document preparation.	ELS		08.12.98	08.12.98
AF08.12.98.01	Prepare notes from 8/6/98 meeting with Grand Prairie building officials.	ELS		09.09.98	09.09.98
AF08.12.98.02	Prepare list of proposed permit packages and timeline. *(Timeline preparation moved to Issues Log item IF09.09.98.01.)*	ELS/LCC		09.09.98	09.09.98
AF08.26.98.01	Issue Crown Corr Agreement.	NS/LCC		09.09.98	09.09.98
AF08.26.98.02	Issue Pacific Agreement.	NS/LCC		09.09.98	09.09.98
AF08.26.98.03	Issue Havens Agreement.	NS/LCC		09.09.98	09.09.98
AF08.26.98.04	Define format/dates for ELS consultants	ELS/LCC		Deleted	09.09.98

	design scope of work. *No one recognized this as an action item or was a duplicate.*				
AF08.26.98.00	Resolve design agreement legal issues with ELS.	NS		09.09.98 09.23.98	To AF 07 .01.98.04
AF08.26.98.05	Prepare cash flow to January 1999 by month for ELS and their consultants based on current value stream (AF10.21.98.01).	ELS	5 5	09.09.98 10.21.98	Combined Below
AF08.26.98.06	Prepare cash flow to January 1999 by month for LCC and consultants based on current value stream (AF10.21.98.01).	LCC	5 5	09.09.98 10.21.98	Combined Below
AF08.26.98.07	Prepare cash flow to January 1999 by month for NS and consultants based on current value stream.	NS		09.09.98	09.09.98
AF08.26.98.08	Issue SPL Agreement letter (IF10.21.98.02).	NS/AA/LCC	5 5	09.09.98 10.21.98	Issues Log 10.21.98
AF09.09.98.01	Bob Timmel to review list of cost increases with Bruce, Pam and Mike on Friday 09.11.98	NS/LCC		09.11.98	09.14.98
AF09.09.98.02	Bob Timmel to review list of cost increases with Leo3.	NS		09.14.98	09.14.98
AF09.23.98.01	Prepare permit package timeline (AF08.12.98.02/ IF09.09.98.01).	ELS/LCC		10.07.98	10.07.98
AF09.23.98.02	Continuing improvement in the planning process: improving ability to make quality assignments and ability to meet commitments (IF10.07.98.01).	All		10.07.98	Issues Log 10.07.98
AF10.07.98.01	Review with each team the most effective way to proceed with the development of construction documents *and target cash flows (IF07.15.98.03)*.	NS/LCC		10.21.98	10.21.98
AF10.21.98.01	Prepare project workplan/target cash flows(w/manhours): design cash flows assume 12.21.98 construction start (AF08.26.98.05, AF08.26.98.06, IF10.07.98.02).	ELS/LCC	5	11.04.98 12.02.98	12.02.98
AF10.21.98.01	Prepare project workplan/target cash flows(w/manhours): construction cash flows assume 02.15.98 construction start and18.5 month construction schedule.	LCC	7	12.02.98	12.16.98
AF11.04.98.01	Early construction/other work to achieve visual site impact.	NS/ELS/ LCC	1	12.02.98	12.16.98
AF11.04.98.02	Develop early value stream for remaining critical early preconstruction items of work.	LCC/NS/ ELS/ HA	7	12.02.98	12.16.98
AF12.02.98.01	Blueline Online: recommendation to not implement until the site is stable.	ELS		12.16.98	
JDK	**End of Action Items**				

APPENDIX D: NEXT STAGE ISSUES LOG

During Next Stage teleconferences, issues requiring action beyond the coming two week period were placed in an issues log, from which they then moved onto the action items log when the timing was appropriate. Issues were numbered in the same way as were action items, except for the IA, IB, etc. prefix.

Linbeck Next Stage Development

The Texas ShowPlace

Issues Log

As Of December 02, 1998 Project Progress Meeting — Revised: 12.14.98

Date Originated-Item No.	*Item Description*	*Action By*	*Target Date*
A. Site/Civil			
IA08.26.98.04	Relocation of on-site pad mounted equipment by Texas Utilities.	HA/TEE	
IA09.09.98.02	Legal Action filed against NS, by local radio station, re: within 2400 ft, operating since 1950's, 'sole station', fear of our metal building.	NS	
IA10.21.98.01	Select electrical yard surface material; if paved, then concrete.	HA	
IA11.04.98.01	Determine the most effective way to contract for the site work (AA12.02.98.05).	HA/LCC	Action Log 12.02.98
B. Structural			
IB08.12.98.01	Review utilization of prefab stairs (IC08.12.98.02, AB12.02.98.04).	ELS/LCC	Action Log 12.02.98

IB09.09.98.03	Review structural connections and heavy steel members. (AB08.26.98.04 & IB07.01.98.01)	HSC/SPI/PB	
IB09.23.98.01	Holding an *02.15.99* start of construction requires steel mill order by *01.15.99*; detailing to start by *02.15.99*; fabrication to start *03.29.99, and erection to start on 05.10.99*	NS/LCC/HSC/ SPI	
IB09.23.98.02	After 3D Model, Foundation and Structural Permit submisssion target *01.04.99* for a *02.05.99* receipt of permit.	HW/ELS	
IB12.02.98.01	Mock-up color selection critical; NS moving on other color decisions based on previously selected building material colors.	NS/ELS	
IB12.02.98.02	Select aggregate/paver material for visible low roof; aggregate is more cost effective if wind load is not an issue.	NS/ELS	
IB12.02.98.03	Provide for access to lobby by larger equipment, 10Ft X 10FT, for automobile, large boom type lift to access relamping.	NS/ELS	

C. Enclosure/Architectural

IC07.29.98.01	Resolve material selection at the building base (AC08.12.98.04).	ELS/LCC	
IC09.09.98.01	Determine if a mock-up(s) of exterior wall will be required; *to be price based (AC12.02.98.01)*.	NS/ELS	Action Log 12.02.98

D. Mechanical/Electrical/Plumbing/Fire Protection

ID07.15.98.01	File application and pay fees for temporary power and telephone four weeks before needed.	NS/LCC	
ID08.12.98.05	Add acoustics value stream into project value stream.	JHSA/LCC	
ID08.26.98.01	Finalize concession design upon selection of concessionaire vendor.	NS/CI/ELS/ CHPA/TEE	
ID10.21.98.01	Block diagram equipment layout by Levy Restaurants	NS/LR	*12.08.98*
ID12.02.98.01	Confirm assumptions regarding lighting controls. *Automated M/P systems can control other timed systems, i.e. parking lighting, etc. Ongoing work issue (AD11.04.98.07).*	CHPA/TEE	

E. Theatrical/Interiors

IE08.26.98.01	Seating count down from 6900 to 6400. May go up to 6550 plus 256 for suites. *Refer to memo of 08.27.98.*	NS/ELS	
IE10.07.98.01	Evaluate continuing scaffolding or working up from structural platforms. Method of construction issue	LCC	

	to be decided by LCC.		
IE12.02.98.01	Obtain sample of Irwin metal pan perforated seat with curved lip. No differential envelope (AE10.07.98.11).	LCC	
IE12.02.98.02	Irwin Seating critical path, 12 months from design to delivery.	NS	
IE12.02.98.03	D.Flannery to layout TV camera positions in the house.	NS	
IE12.02.98.04	Price Division 16 infrastructure for video and communication.	LCC	
IE12.02.98.05	Provide video communication equipment price.	JHSA	

F. Project Support

IF07.01.98.01	Develop post-preconstruction contract documents for review.	LCC	
IF07.15.98.02	Integrate preconstruction agreement with GMP contract.	LCC	
IF07.15.98.04	Develop *site utilization/mobilization plan*.	LCC	
IF07.29.98.01	Define long term role of food service consultant.	NS	
IF07.29.98.02	Review/revise Value Stream in relation to schedule revisions, project changes, etc.	LCC	
IF08.12.98.01	Resolution of project insurance program.	All	
IF08.26.98.01	Issue subcontractor preconstution agreements for discussion, (AF07.01.98.03). Crown Corr agreement issued.	All	
IF08.26.98.02	Identify potential national vendor partners. Effort continuing (AF07.01.98.06).	LCC/ELS	
IF08.26.98.03	Probability of construction start date - Status Report (AF07.15.98.02).	NS	
IF08.26.98.04	Expand current summary project budget to detailed estimate when 3-D model has been completed.(AF07.29.98.02/IF09.09.98.02).	LCC	
IF09.09.98.03	Define a point in the design process where it makes sense to stop additional work until a definitive construction start date is known; and, independent of a construction start date.	NS/ELS/CHPA/TEE/LCC	
IF09.09.98.04	Define how, and at what point, cost escalation becomes a consideration.	NS/LCC	
IF10.07.98.01	Continuing improvement in the planning process; improving ability to make quality assignments and ability to meet commitments (AF09.23.98.02).	All	
IF10.21.98.01	Resolve design agreement legal issues and complete ELS design agreement. *Effort continuing. Documents may not be filed for permits until legal issues are resolved and designers can be identified in the drawing title block (AF07.01.98.04).*	NS/ELS	11.28.98
IF10.21.98.02	Issue SPL Agreement letter (AF08.26.98.08).	NS/AA/LCC	*12.16.98*

IF10.21.98.03	Identify items critical to value stream and follow through; be clear about what should be on the value stream.	ALL
IF12.02.98.01	Concession architect:Lawrence Berkely Associates. Plans and room finishes to be sent to NS. Counters and facade to be allowances; LCC to construct shell.	NS

JDK **End of Issues**

APPENDIX E: NEXT STAGE DECISION LOG

Next Stage maintained a log of design decisions, numbered similarly to action items and issues, but with a DA prefix for Site/Civil, DB for Structural, etc.

Decision Log

As Of December 02, 1998 Project Progress Meeting Revised: 12.14.98

Date Originated-Item No.	*Item Description*	*Decision By*	*Decision Date*
A. Site/Civil			
DA07.15.98.01	Retain the services of a TAS Accessibility Specialist.	NS:RT	07.15.98
DA07.15.98.02	There will be multiple collection points for storm and sanitary drainage around the building (IA07.01.98.03).	CHPA:GP HA:JR	07.15.98
DA07.29.98.01	Specify same site and parking lighting fixtures as Lone Star Park, unless not feasible or too costly.	NS:RT	07.29.98
DA07.29.98.02	Barrier Free Texas selected as Accessibility Specialist.	NS:RT/ELS :KS	07.29.98
DA07.29.98.03	Uncertain timetable does not allow taking borrow material from existing sewer contractor.	NS:RT	07.29.98
DA08.12.98.01	Use existing lighting for Road D, rewired for new/joint operation with Lone Star Park.	NS:RT	08.12.98
DA08.12.98.02	Grading permit approval does not require architectural document submission.	ELS:DF	08.12.98
DA08.26.98.01	Roadway and building relationships are not affected by the commissary.	HA:JR	08.26.98
DA08.26.98.02	Commissary **Scheme A** selected *(reversal from Scheme B).*	NS:BC	08.26.98
DA08.26.98.03	Roof drain overflow to be piped into primary drainage system.	CHPA:GP	08.26.98
DA09.09.98.01	Commence geotechnical exploration/drilling of LSP borrow material.	NS:RT	09.09.98
DA10.07.98.01	Utilize 55 foot light poles in parking area.	TEE:CS	10.07.98
DA11.04.98.01	If GPISD material is available at the start of construction, then will make an offer for subgrade material for automobile parking.	NS:RT	11.04.98

B. Structural

DB07.15.98.01	Cantilever balcony structure is not practical nor feasible; *cross aisles raised to make cantilever work.*	JA:HW KS:ELS	07.15.98 08.26.98
DB07.29.98.01	Tapered beams will be utilized to support the balcony.	HW:JA/ ELS:KS	07.29.98
DB08.12.98.01	There will be no electrical point loads in the structure greater than 500 lbs (AB07.01.98.08).	TEE:CS	08.12.98
DB08.12.98.02	Design criteria for building exterior will be based upon wind tunnel test results (AB07.01.98.14).	HW:RT	08.12.98
DB08.12.98.03	Resolved audience reduction and box beam loads and location.	ELS:KS / AA:AS	08.12.98
DB08.12.98.04	Proceed with structural design based upon existing perimeter envelope and seating platform.	NS:RT	08.12.98
DB08.12.98.05	Extend four week steel fabrication schedule from 4 weeks to 6 weeks (IB07.15.98.03 / AB08.12.98.01).	HSC:JK	08.12.98
DB08.12.98.06	Resolved low roof impact on structural design by selecting concession scheme 'B'. *Reversed to Scheme A.*	NS:BC NS:BC	08.12.98 08.26.98
DB08.12.98.07	Project will not start construction 09.15.98; and, will not utilize warehouse steel.	NS:RT	08.12.98
DB08.12.98.08	Acceptable construction tolerance on seating is 1/2" per riser, platform to platform.	ELS:KS	08.12.98
DB09.09.98.01	Initial steel mill order must be made 1 month prior to start of construction.	HSC:JK	09.09.98
DB09.23.98.01	Complete 3D model check; hold-up connection study, detailing, and, trans-mission of 3-D model until resolution of potential seating layout change.	NS:RT	09.23.98
DB10.07.98.01	Eliminate CMU walls at FOH mechanical rooms due to revised AHU layout.	JHSA:RL	10.07.98
DB12.02.98.01	Revise column locations at rear of stage house to center the door.	BC:NS	12.02.98

C. Enclosure/Architectural

DC07.01.98.01	Construction/shop drawings not necessary to provide GMP for exterior wall enclosure.	CC:SC	07.01.98
DC07.15.98.01	There is not a food service requirement for louvers (IC07.01.98.05).	CHPA:GP	07.15.98
DC07.15.98.02	The site has a "quiet area" designation relating to outside area noise.	JHSA:RL	07.15.98
DC07.15.98.03.	GMP for roof can be provided without having the roof design completed.	PC:TZ	07.15.98

DC08.12.98.01	Walls to be rated R20 & Roof R30 Insulation (IC07.15.98.01 / AC08.12.98.02).	CHPA:GP LCC:BP	08.12.98
DC08.26.98.01	R30 Roof and R20 Wall will be the thermal transmission ratings used.		08.26.98
DC08.26.98.02	Roof design by Pacific to follow Crown Corr drawings.	PC:TZ	08.26.98
DC10.07.98.01	Can specify custom metal panel colors based upon nominal price increase.	NS:RT	10.07.98

D. Mechanical/Electrical/Plumbing/Fire Protection

DD07.15.98.01	TEE:CS to participate in evaluating online project management approach.	TEE:CS	07.15.98
DD07.29.98.01	FE:WMcD to participate in evaluating online project management approach.	FE:WMcD	07.29.98
DD08.12.98.01	The raceway loads will not affect structural point loading (AD07.01.98.13).	TEE:CS HW:RT	08.12.98
DD08.12.98.02	Location of main electrical room and electronics storage will maintain existing relationship.	TEE:CS LCC:MI	08.12.98
DD08.12.98.03	The back of the house will be a no smoking area.	NS:BC	08.12.98
DD08.12.98.04	Utilize 75 KVA as added electrical load from commissary.	TEE:CS	08.12.98
DD08.26.98.01	Proceed with concession/commissary MEP design based on current 08.26.98 consultant concept/interim design criteria.		08.26.98
DD08.26.98.02	HVAC design is to be per ASHRAE standards, as shown in current Project System Description.	CHPA:GP	08.26.98
DD08.26.98.03	Provide individual climate control in suites.	NS:BC	08.26.98
DD09.09.98.01	Smoking area includes suites and select concession areas (Rooms 123,124)	NS:BC	09.09.98
DD09.23.98.01	Proceed with 21,000 cfm lobby smoke exhaust as opposed to a house/lobby rated separation.	NS:BC,ELS :KS CHPA:GP	09.23.98

E. Theatrical/Interiors

DE07.01.98.01	NC 25 accepted as design criteria.	JHSA:CJ	07.01.98
DE07.29.98.01	Provide suite level public toilet rooms; eliminate toilet rooms in suites, but provide infrastructure MEP.	NS:RT	07.29.98
DE07.29.98.02	Provide expanded commissary kitchen and support areas.	NS:RT	07.29.98
DE08.26.98.01	Sound and lighting control house *mix position* cannot be moved into rear aisle due to handicapped seating quota. This room requires the size shown on sketch current as of 08.26.98.	JHSA:DR ELS:KS	08.26.98
DE08.26.98.02	Hold on final concession design for contracted concessionaire.	NS:RT	08.26.98

DE09.23.98.01	Box Booms will be rigged.	NS:BC	09.23.98
DE10.07.98.01	Change seating configuration to curved format.	NS:RT	10.07.98
DE10.07.98.02	Provide proscenium deluge system with opaque curtain.	NS:RT ELS:KS	10.07.98
DE10.07.98.03	There will not be a front balcony projection position.	NS:BC	10.07.98
DE10.07.98.04	Eliminate the rigging pit due to revised counterweight design.	AA:AS	10.07.98
DE10.21.98.01	Utilize Video/TV/Broadcast scope prepared by AA/JHSA to define building infrastructure to be provided.	NS:BC	10.21.98
DE12.02.98.01	Approximately 95% of speakers will be rigged or stacked on stage; all lighting and sound support will be within 60 Feet of stage.	NS:BC AA:AS	12.02.98

F. Project Support

DF07.01.98.01	It is not necessary to follow Factory Mutual design criteria.	NS:RT	07.01.98
DF07.01.98.02	Project progress meetings will utilize "Last Planner" style.	NS:RT	07.01.98
DF07.15.98.01	Design process to maintain 21 month value stream production schedule.	NS:RT	07.15.98
DF07.15.98.02	Multiple submissions will be made to the City to satisfy the needs of obtaining multiple permit approvals.	NS:RT	07.15.98
DF09.23.98.01	Keep the design process progressing toward an 11.30.98 construction start; the only reason to hold up progress of the drawings is if it is not efficient for the design to proceed.	NS:LL	09.23.98

End of Decisions

NATURE OF CONSTRUCTION TECHNOLOGY

Andrew S. Chang[1] and Kuan Pei Lee[2]

ABSTRACT

Construction management studies address mostly the phenomena of construction problems. Few studies explore the nature of construction technology or production systems.

Technologies in manufacturing are classified into unit, mass and continuous process productions and their characteristics are examined. Construction fabrications and activities are contrasted to classify construction technology as unit production. Furthermore, technical change is studied and limitations to the change of construction technology are proposed.

Although the efficiency of construction technology as unit production is low, it has many advantages such as flexibility and zero stocks. The appearance of new production systems will not replace the old unit production. Although the final construction products could not be standardized entirely, we can standardize their components, and rethink their assembling and integrating methods to increase production efficiency.

KEY WORDS

Construction technology, production system, unit production, mass production, continuous process, product, automation, technical change

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INTRODUCTION

Construction is the major process in the construction project life cycle and many parties are involved. For a long time construction productivity has not been satisfactory. Improvement studies mostly focus on construction activities, while few studies explore the nature of construction technology or production systems (Howell 1999).

Since industrial revolution, people keep looking for efficient production systems. Departing from the earliest built-to-order production, manufacturing and industrial process plants adopted mass, continuous process, flexibility, and even advanced IT production systems to gain advantages in efficiency and effectiveness. However, the construction process has none of the characteristics of the modern manufacturing (Bertelsen 2002).

Most construction projects are still built under the traditional way of one-of-a-kind production. The use of IT in construction has often failed to produce the results intended. These inefficiencies of operations may largely result from particular complexity factors owing to industry specific uncertainties and interdependences (Dubois and Gadde 2002). Therefore, it needs to understand the nature of construction technology more to explain these phenomena, and a theory of construction production to solve the problems (Koskela 2000).

This study contrasts construction practice with technology theory. It defines construction technology, compares characteristics of different technologies, discusses technical change and construction technology's limitation, and finally presents improvement strategy for the construction industry.

DEFINITION OF TECHNOLOGY

Technology has different meanings and definitions. In manufacturing, technology has often been used interchangeably with the production system. Daft (2004) defines technology as the tools, techniques, machines, and actions used to transform organizational input (materials and information) into output (products and services). Slack et al. (1995) also see production as a transformation process. In addition to the transformation process, Koskela (2000) sees the production as a flow to reduce waste and a value generation process to meet customer needs. These definitions are shown in Figure 1: the core circle is the transformation process, the input-process-output is a flow, and the output products or services have to meet customer needs.

Technology includes hard machinery and soft work procedures. Most literature of technology emphasizes the hardware aspect such as machine and techniques but neglects the software aspect such as methods of working and managing. Technology influences performance and achievement of strategic objectives. The software of the transformation process is like tacit knowledge that is worth exploring in depth to supplement hardware to achieve better performance.

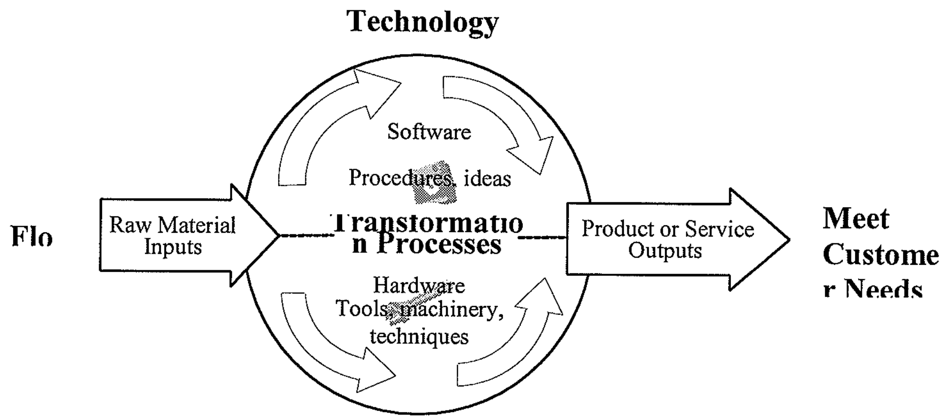

Figure1. Definition of Technology

CONSTRUCTION TECHNOLOGY

Woodward (1994) classified production systems into unit and small-batch production, large-batch and mass production, and continuous process production according to technical complexity of the manufacturing process. Technical complexity represents the extent of mechanization of the production process. Similarly, Schmenner (1993) divided manufacturing processes into a spectrum of five major types: project, job shop, batch flow, line flow, and continuous flow.

In Woodward's scale of technical complexity, the three groups are originally consolidated from ten categories. Typical construction component fabrications and jobsite activities are compared with the ten categories as shown in Table 1.

It can be seen that most construction jobsite activities belong to unit production. For the first of the ten categories, the production of single pieces of customer orders means build by project. When the project is divided into jobsite activities, concrete pouring belongs to this category because its activities are arranged into pieces following finished steal bar and formwork. The steal bar and formwork are prepared as technically complex units one by one such as beams and columns, which is one level up in the technical complexity and belong to the 2nd category. Precasting, a kind of standardization work learned from manufacturing, belongs to the 3rd category of fabrication of large equipment in stages.

Hence, construction is a kind of unit production based on the majority of jobsite activities. Although some component fabrications reach the mass or continuous process production level such as cement plant and building materials, they are mostly done by suppliers or fabricators, not constructors in the construction supply chain (Ballard and Howell 1998).

Fabrications of construction components are better performed than construction jobsite activities. The challenges for construction management are to assemble or integrate these fabricated components into better planned and executed construction activities.

Table 1. Construction Activities in Technology Categories

	Technology Classification		Component Fabrications	Jobsite Activities
Small-batch and unit production	1	Production of single pieces of customer orders	Build by project	Concrete pouring
	2	Production of technically complex unit one by one		Steel bar tying, formwork
	3	Fabrication of large equipmment in stages		Precasting
	4	Production of pieces in small batches		Excavation
Large-batch and mass production	5	Production of components in large batches subsequently assembled diversity	Concrete batch plant	
	6	Production of large batches, assembly line type	Assembly house	
	7	Mass production	Cement plants	
Continuous process production	8	Continuous process production combined with the preparation of a product for sale by large-batch or mass production methods	Building materials	
	9	Continuous process production of chemicals in batches	Paint plant	
	10	Continuous flow production of liquids, gases, and solid shapes		

TECHNOLOGY CHARACTERISTICS

Service and manufacturing are the two main types of technology in organizations. Their characteristics are compared in Figure 2. Service technology emphasizes the process and manufacturing addresses the product. The construction industry is in the middle, characterized by a combination of the two. For example, the contractor needs to interact with the owner very closely, just like the service. She also builds tangible structures, the same as manufacturing.

A number of construction studies expect to copy successful experience from manufacturing. However, lessons can be learned only to certain extent since their characteristics are not the same (Ballard and Howell 1998). That is, construction needs to find out its own nature and develop its own stories.

Service Technology	Construction Technology	Manufacturing Technology
1. Intangible output *2. Quality is percieved and difficult to measure* *3. Labor and knowledge intensive* *4. Customer interaction generally high* *5. Rapid response time*	**Service and Product**	*1. Tangible product* *2. Quality is directly measured* *3. Capital asset intensive* *4. Little direct customer interaction* *5. Longer response time is acceptable*

Figure 2. Characteristics of Services and Manufacturing

The characteristics of three technologies are compared in Table 2. Unit production tends to be job shop operations that manufacture and assemble small orders to meet specific needs of customers. It relies heavily on the human operator and is not mechanized. Although machinery is used for part of the produciton process, final assembly requires highly skilled human opertions to ensure reliability of products. Mass production is characterized by long production runs of standardized parts. Output often goes into inventory from which orders are filled. Examples include most assembly lines. In continuous process production, the entire process is mechanized and there is no starting and stopping. Examples include chemical plants and refineries.

Table 2. Technology Characteristics

Technology / Characteristics	Unit Production (Construction)	Mass Production	Continuous Process Production
Process predictability	Low (High uncertainty)	Medium	High
Mechanization	Low (Labor intensive)	Medium	High
Batch	Small (Pieces)	Medium	Large
Product complexity	Integral (Heavy integration)	Assembly or components	Dimensional
Standardization	Low (Less duplication)	Middle	High (less types)
Sale	Production to orders (by contract)	Inventory	Some inventory difficult to store

The characteristics of construction technology are similar to those of unit production. Construction's process predictability is low because of high uncertainty that resulting in actual deviation from planning. Mechanization is low because of labor intensive. Many activities are operated in small batches or pieces. Products are highly complex that requires heavy integration. Standardization is low because of unique design, less duplication, or little repetitiveness. And the construction project is operated by contract.

FORCES OF TECHNICAL CHANGE

Competitive pressures often drive firms to adopt new technologies to differentiate from competitors or to gain a cost advantage (Porter 1985). Market pull and technology push are two forces that strongly influence the adoption of new technologies (Mowery and Rosenberg 1979), as shown in Figure 3. Market pull forces come mainly from customer needs. Technology has to change when the market changes and the old technology can not meet customer needs. The market pull drives organizations to change from top down to modify strategic objectives and adopt more advanced systems. For example, a unit production is changed to mass production when the difference of customer needs in the market decreases.

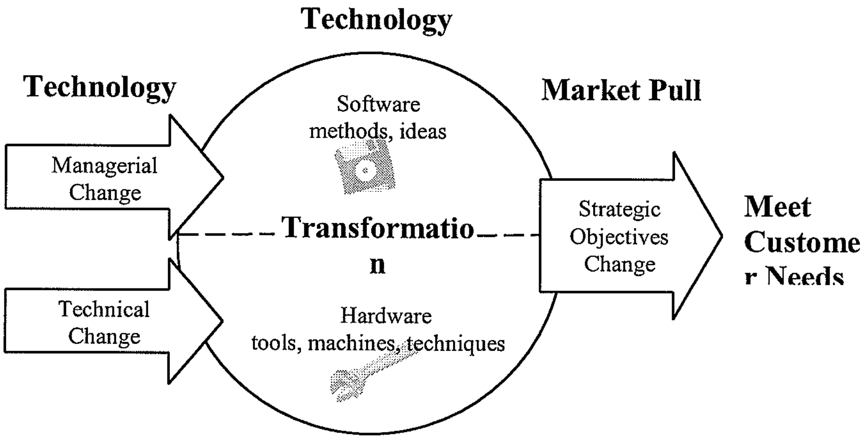

Figure 3. Driving Forces of Technical Change

Technology push causes a bottom up change. This change occurs when hardware and software techniques develop that enables organizations to use new and more effective means to achieve organization goals. Technology push includes the hard technical change and soft managerial change, in which management methods, processes, and procedures have to be compatible with the machines, tools, and techniques.

Market pull forces are the primary influence on the technical change compared to technology push (Mitropoulos and Tatum 2000). Studies of new product and process development also support the argument that market pull forces are the primary influence on innovation compared to technology push (Myers and Marquis 1969; Langrish et al. 1972). That is, customer needs drive the transformation process change.

CHANLLEGES FOR CONSTRUCTION TECHNICAL CHANGE

It is important to have good precognition of problems when leading a technical change. The challenges of construction technical change are illustrated in Figure 4. Three major problems are the broken junction, jumbled jobsite process, and vague demands from unclear customers. In the front component fabrication part, mass or continuous process production approach is allowed to generate steady work flow. Once reaching the junction with jobsite activities, the flow becomes turbulent that requires the unit production to handle subsequent jumbled processes. We can see many construction supply chain endeavors design material supply or web-based bidding well, but stop at the jobsite activities. Customer needs are indeed important to know. But customers of construction projects are unclear. Are they users? Where are they? What are their needs? The needs are usually vaguely explained by owners and/or designers in the front and change afterwards (Bertelsen 2002).

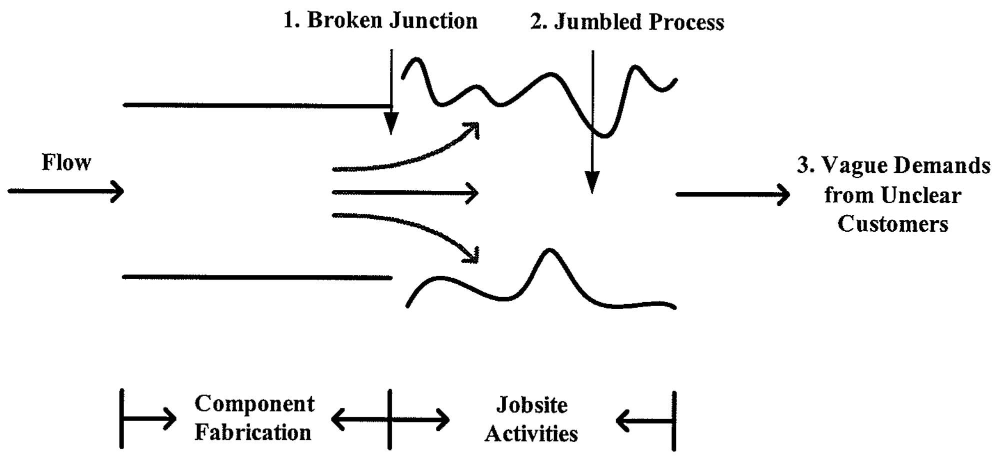

Figure 4. Challenges of Construction Technical Change

Combination of two processes is common for many productions. The reason for the hybrid process is that one part such as batch flow is not as nimble as the other part such as continuous flow (Schmenner 1993). In most hybrid processes, the second part is more nimble than the first to quicken the whole process (Schmenner 1993). However, in the construction hybrid process in Figure 4, the second part of jobsite process slows down the whole process.

Although lean engineering and manufacturing is based on standardization (GM 1997), the essence of jumbled construction jobsite activities restrict process standardization. Gibb (2001) pointed out that houses are not cars and maximum standardization is not always the answer. It is also difficult to standardize construction products because each project, owner, or designer demands differently. Automation is achieved through continuous standardizing and optimum production process. If not standardized, it will be even more difficult for construction technology to change to automation.

The construction market usually reflects customer needs on the front-end materials and final products. Specifications specify requirements mostly on material quality and safety standards. The technology is usually not the focus. Therefore, it may not raise competitiveness but cause problems if a firm adopts new technology for the sake of technology push, without knowing the real market needs.

Another limitation to change is the work availability. The initial investment cost of standardization or automation is high. Construction firms are unwilling to take risks under the uncertain market. Unless a large number of work orders are available in the market and in the future, few construction firms will have long term plans. However, the construction markets in many countries are mature. Many firms are developing overseas markets in the developing countries.

STRATEGY BASED ON CONSTRUCTION TECHNOLOGY

Table 3 compares the technical complexity with product complexity. Although the technical complexity of unit production is low, it demands integral products so the product complexity is high. Since the integral products are created with low mechanization, people working in the process have great discretion (Dubois and Gadde 2002). At the same time the manual integration brings tremendous interaction between people. These distinct features satisfy social needs as well as imply the importance of individual experience and interpersonal skills. In contrast, technical complexity is high and products are simple for mass or continuous production. The repetitive production process and early product planning tend to make people in work feel bored and less challenge.

Table 3. Technical and Product Complexity Comparison

	Technical Complexity	**Product Complexity**
Unit Production	Low	High (Integral Product)
Mass Production	Medium	Medium (Components)
Continuous Process Production	High	Low (Dimensional Product)

Every kind of technology has its pros and cons and suitable applications. The appearance of new technology does not mean that the old one is out of date. Lessons from construction technology can be learned by other industries. In the automobile industry, the firms gradually perform only the core tasks and adopt outsourcing. Production systems also change from large-scale plants on pursuing maximum economic scale to small-scale plants in order to be close to customers and response production demands (Economist 2002). In construction, outsourcing (i.e. subcontracting) is widely used and closeness to customers (owners) is common.

Construction should take advantage of the flexibility instead of over-standardizing. Each construction project has distinct characteristics, location, period, and aesthetics demands. These flexibilities do not give up pursuing efficiency and effectiveness. Although it is unlikely to standardize the very end products, their components are possible. In this regard, lessons can be learned from the mass or continuous process productions. Precast construction is an efficiency example. Design for manufacture or constructability is another effectiveness example (Fox et al. 2001).

The ultimate construction products depend largely on the collaboration of project participants and integration of tasks during the construction process (Peña-Mora and Tamaki 2001). The very techniques needed for the construction industry would be the coordination mechanisms across organizations and participants to integrate construction supply chain activities.

CONCLUSION

Construction technology produces products at the same time providing services. It is a kind of unit production and highly customized. Projects are constructed to orders with zero stock. The construction process is highly uncertain and predictability is low. Although technical complexity is low with the production system, it can make the highly complicated products. Many intermediate products are created and integrated by human operators with low mechanization, standardization, and automation.

Limitations should be considered when pursuing construction technical change. It should be out of market pull driven by customer needs; address standardization of construction components only; and base on market work availability. The advantages of construction technology include zero stock, high flexibility, and satisfactory social needs. With these advantages appreciated, the construction industry should pursue the integration improvement of construction jobsite activities.

Construction automation had been promoted to advance production efficiency for past years. Moreover, the issue of electronic business also has been included recently. The automated construction systems are poorly progressed compared with those in the manufacturing industry. It may largely be limited by the nature of construction technology. Thus, we should understand and examine the construction technology fundamentally before pushing successive construction automation and e-construction programs.

ACKNOWLEDGEMENTS

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Nature of Construction Technology

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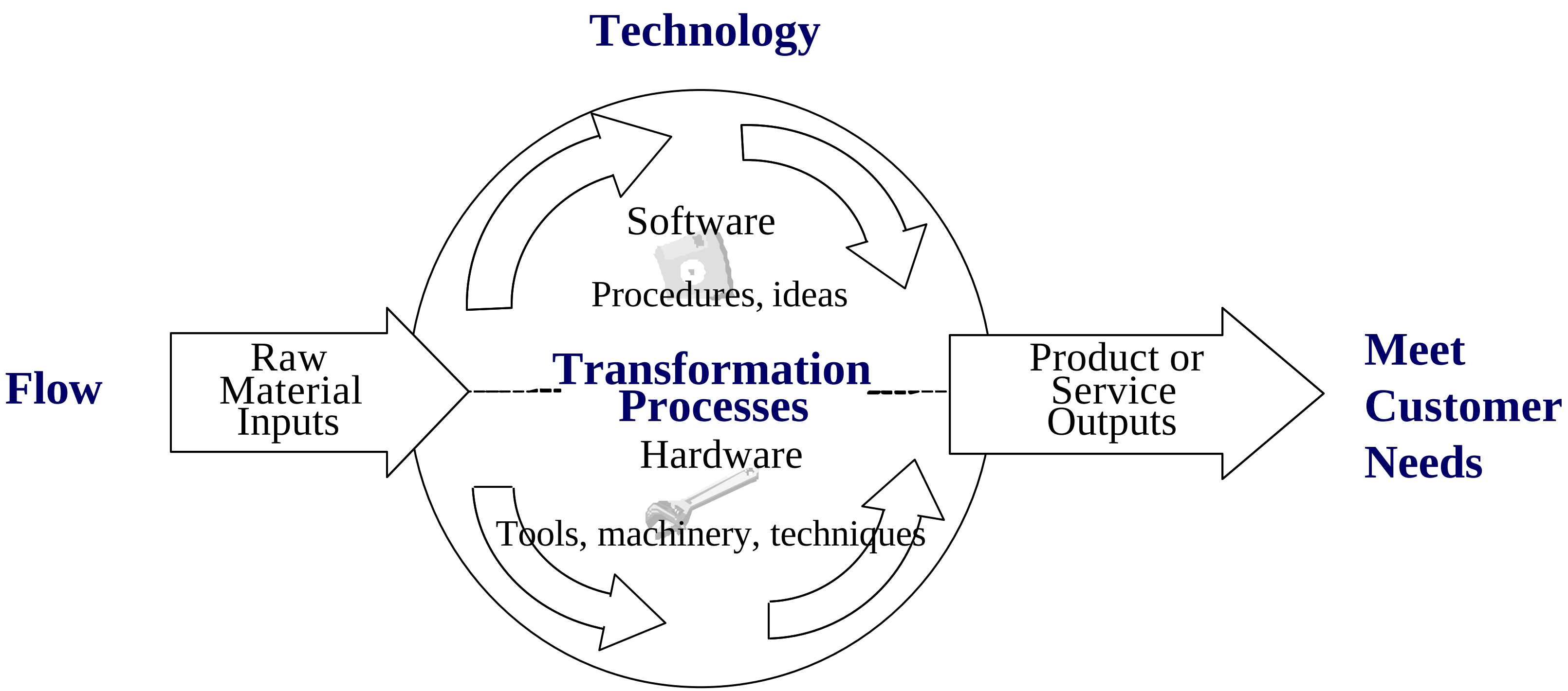
August 3, 2004

Technology Definition



Construction Activities in Technology Categories

		Technology Classification	Component Fabrications	Jobsite Activities
Small-batch and unit production	1	Production of single pieces of customer orders	Build by project	Concrete pouring
	2	Production of technically complex unit one by one		Steel bar tying Formwork
	3	Fabrication of large equipmment in stages		Precasting
	4	Production of pieces in small batches		Excavation
Large-batch and mass production	5	Production of components in large batches subsequently assembled diversity	Concrete batch plant	
	6	Production of large batches, assembly line type	Assembly house	
	7	Mass production	Cement plants	
Continuous Process production	8	Continuous process production combined with the preparation of a product for sale by large-batch or mass production methods	Building materials	
	9	Continuous process production of chemicals in batches	Paint plant	
	10	Continuous flow production of liquids, gases, and solid shapes		

Technology Characteristics

Characteristics \ Technology	Unit Production (Construction)	Mass Production	Continuous Process Production
Process predictability	Low (High uncertainty)	Medium	High
Mechanization	Low (Labor intensive)	Medium	High
Batch	Small (Pieces)	Medium	Large
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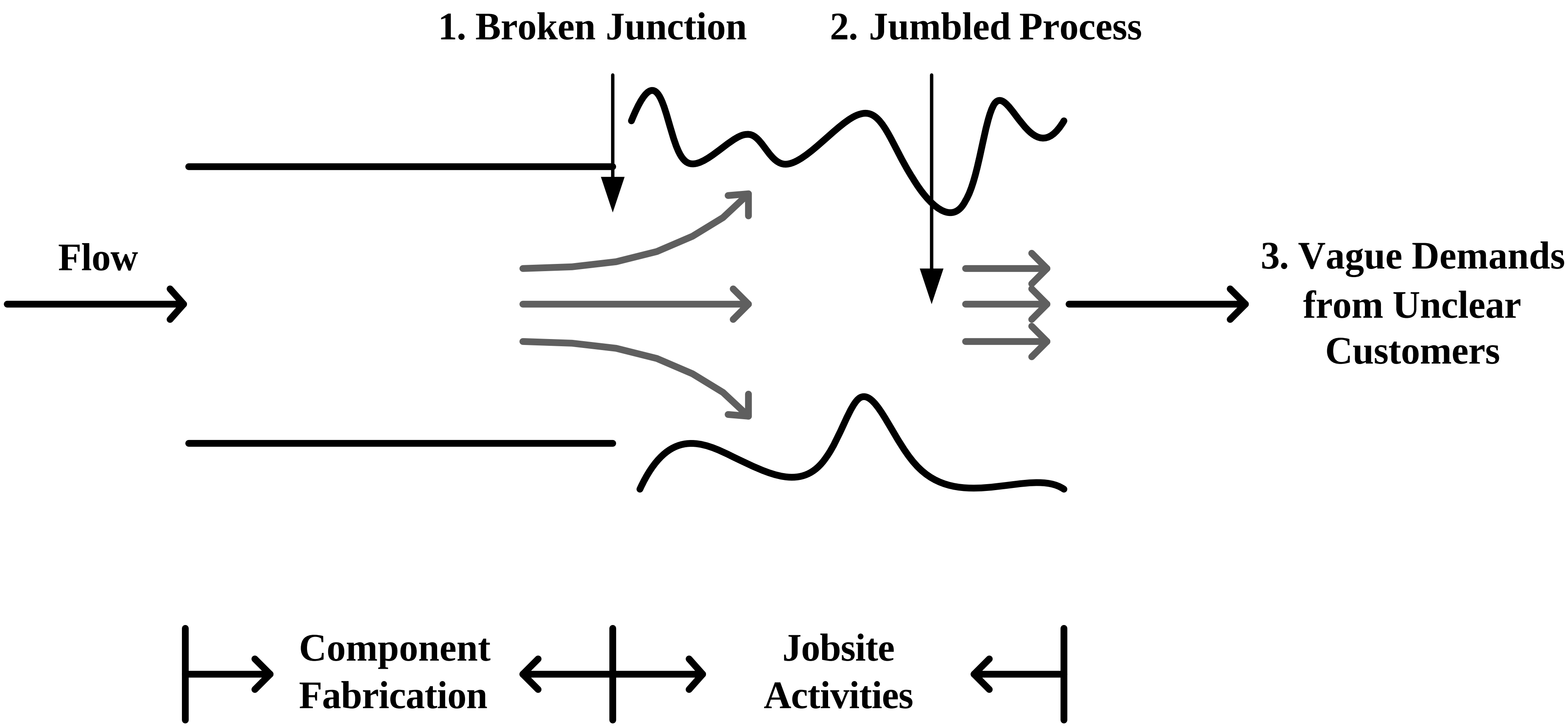
Sale	Production to orders (by contract)	Inventory	Some inventory difficult to store

Challenges of Construction Technical Change



Conclusion

- Advantages
  - Constructed to orders with zero stock
  - High flexibility
  - Satisfactory social needs
- Limitations
  - Be out of market pull
  - Standardizing mainly construction components
  - Based on market work availability
- Should pursue coordination and integration of jobsite activities

RETHINKING CONSTRUCTION

THE REPORT OF THE CONSTRUCTION TASK FORCE

Rethinking Construction

The report of the Construction Task Force to the
Deputy Prime Minister, John Prescott, on the scope for
improving the quality and efficiency of UK construction.

CONTENTS

Foreword by Sir John Egan

Deputy Prime Minister

“It gives me great pleasure to present the report of the Construction Task Force on the scope for improving quality and efficiency in UK construction.

A successful construction industry is essential to us all. we all benefit from high quality housing, hospitals or transport infrastructure that are constructed efficiently. At its best the UK construction industry displays excellence. But, there is no doubt that substantial improvements in quality and efficiency are possible. Indeed, they are vital if the industry is to satisfy all its customers and reap the benefits of becoming a world leader. The Construction Task Force wishes to see the dramatic improvements already being demonstrated on client-led projects spread throughout UK construction.

In formulating our proposals for improving performance we have studied the experience that has been gained at the cutting edge of construction and in other industries that have transformed themselves in recent years. We have learnt that continuous and sustained improvement is achievable if we focus all our efforts on delivering the value that our customers need, and if we are prepared to challenge the waste and poor quality arising from our existing structures and working practices.

We know that it is not easy to sustain radical improvement in an industry as diverse as construction. But, we must do so to secure our future. Through the Task Force, the major clients have committed themselves to driving forward the modernisation of the construction industry. We look to Government, as the largest client, to join us. But, we are also issuing a challenge to the construction industry to commit itself to change, so that, working together, we can create a modern industry, ready to face the new millennium.”

Sir John Egan
Chairman of the Construction Task Force

Executive Summary

- The UK construction industry at its best is excellent. Its capability to deliver the most difficult and innovative projects matches that of any other construction industry in the world (paragraph 3).

- Nonetheless, there is deep concern that the industry as a whole is under-achieving. It has low profitability and invests too little in capital, research and development and training. Too many of the industry's clients are dissatisfied with its overall performance (paragraphs 4-6).

- The Task Force's ambition for construction is informed by our experience of radical change and improvement in other industries, and by our experience of delivering improvements in quality and efficiency within our own construction programmes. We are convinced that these improvements can be spread throughout the construction industry and made available to all its clients (paragraphs 15, 16 and 18).

- We have identified five key drivers of change which need to set the agenda for the construction industry at large: *committed leadership, a focus on the customer, integrated processes and teams, a quality driven agenda and commitment to people* (paragraph 17).

- Our experience tells us that ambitious targets and effective measurement of performance are essential to deliver improvement. We have proposed a series of targets for annual improvement and we would like to see more extensive use of performance data by the industry to inform its clients (paragraphs 19-22).

- Our targets are based on our own experience and evidence that we have obtained from projects in the UK and overseas. Our targets include annual reductions of 10% *in construction cost and construction time. We also propose that defects in projects should be reduced by 20% per year* (paragraphs 23-26).

- To achieve these targets the industry will need to make radical changes to the processes through which it delivers its projects. These processes should be explicit and transparent to the industry and its clients. The industry should create an integrated project process around the four key elements of *product development, project implementation, partnering the supply chain and production of components.* Sustained improvement should then be delivered through use of techniques for eliminating waste and increasing value for the customer (chapter 3).

- If the industry is to achieve its full potential, substantial changes in its culture and structure are also required to support improvement. The industry must provide *decent and safe working conditions and improve management and supervisory skills* at all levels. The industry must design projects for ease of construction making maximum use of standard components and processes (paragraphs 53-61).

- The industry must replace competitive tendering with *long term relationships* based on clear measurement of performance and *sustained improvements in quality and efficiency* (paragraphs 67- 71).

- The Task Force has looked specifically at housebuilding. We believe that the main initial opportunities for improvements in housebuilding performance exist in the social housing sector for the simple reason that most social housing is commissioned by a few major clients. Corporate clients – housing associations and local authorities – can work with the housebuilding industry to improve processes and technologies and develop quality products. We propose that a forum for improving performance in housebuilding is established (paragraphs 75- 79).

- The Task force has concluded that the major clients of the construction industry must give leadership by implementing projects which will demonstrate the approach that we have described. We want other clients, including those from across the public sector, to join us in sponsoring demonstration projects. We also wish to see the construction industry join us in these projects and devise its own means of making improved performance available to all its clients. Our ambition is to make a start with at least £500 million of demonstration projects (paragraphs 82-83).

- In sum, we propose to initiate a movement for change in the construction industry, for radical improvement in the process of construction. This movement will be the means of sustaining improvement and sharing learning (paragraph 84).

- We invite the Deputy Prime Minister to turn his Department's Best Practice Programme into a knowledge centre for construction which will give the whole industry and all of its clients access to information and learning from the demonstration projects. There is a real opportunity for the industry to develop independent and objective assessments of completed projects and of the performance of companies (paragraph 85).

- The public sector has a vital role to play in leading development of a more sophisticated and demanding customer base for construction. The Task Force invites the Government to commit itself to leading public sector bodies towards the goal of becoming best practice clients seeking improvements in efficiency and quality through the methods that we have proposed (paragraphs 86-87).

- The members of the Task Force and other major clients will continue their drive for improved performance, and will focus their efforts on the demonstration projects. We ask the Government and the industry to join with us in rethinking construction.

CHAPTER 1

The Need to Improve

1. The Construction Task Force has been set up by the Deputy Prime Minister against a background of deep concern in the industry and among its clients that the construction industry is under-achieving, both in terms of meeting its own needs and those of its clients.

2. Construction in the UK is one of the pillars of the domestic economy. The industry in its widest sense is likely to have an output of some £58 billions in 1998, equivalent to roughly 10% of GDP and employs around 1.4 million people. It is simply too important to be allowed to stagnate.

3. UK construction at its best is excellent. We applaud the engineering ingenuity and design flair that are renowned both here and overseas. The industry is also eminently flexible. Its labour force is willing, adaptable and able to work in the harshest conditions. Its capability to deliver the most difficult and innovative projects matches that of any other construction industry in the world.

The Terms of Reference of the Construction Task Force

To advise the Deputy Prime Minister from the clients' perspective on the opportunities to improve efficiency and quality of delivery of UK construction, to reinforce the impetus for change and to make the industry more responsive to customer needs.

The Task Force will:

- quantify the scope for improving construction efficiency and derive relevant quality and efficiency targets and performance measures which might be adopted by UK construction;
- examine current practice and the scope for improving it by innovation in products and processes;
- identify specific actions and good practice which would help achieve more efficient construction in terms of quality and customer satisfaction, timeliness in delivery and value for money;
- identify projects to help demonstrate the improvements that can be achieved through the application of best practice.

The Deputy Prime Minister wishes especially to be advised on improving the quality and efficiency of housebuilding.

The members of the Construction Task Force
Sir John Egan (Chairman), Chief Executive, BAA plc.
Mike Raycraft, Property Services Director, Tesco Stores Ltd.
Ian Gibson, Managing Director, Nissan UK Ltd.
Sir Brian Moffatt, Chief Executive, British Steel plc.
Alan Parker, Managing Director, Whitbread Hotels.
Anthony Mayer, Chief Executive, Housing Corporation.
Sir Nigel Mobbs, Chairman, Slough Estates and Chief Executive, Bovis Homes.
Professor Daniel Jones, Director of the Lean Enterprise Centre, Cardiff Business School.
David Gye, Director, Morgan Stanley & Co Ltd.
David Warburton, GMB Union.

Need to Modernise

4. Nevertheless, the industry recognises that it needs to modernise in order to tackle the severe problems facing it, not least that:

- it has a low and unreliable rate of profitability. Margins are characteristically very low. The view of the Task Force is that these are too low for the industry to sustain healthy development and we wish to see those companies who serve their clients well making much better returns;

- it invests little in research and development and in capital. In-house R & D has fallen by 80% since 1981 and capital investment is a third of what it was twenty years ago. This lack of investment is damaging the industry's ability to keep abreast of innovation in processes and technology;

- there is a crisis in training. The proportion of trainees in the workforce appears to have declined by half since the 1970s and there is increasing concern about skill shortages in the industry. Too few people are being trained to replace the ageing skilled workforce, and too few are acquiring the technical and managerial skills required to get full value from new techniques and technologies. Construction also lacks a proper career structure to develop supervisory and management grades;

- too many clients are undiscriminating and still equate price with cost, selecting designers and constructors almost exclusively on the basis of tendered price. This tendency is widely seen as one of the greatest barriers to improvement. The public sector, because of its need to interpret accountability in a rather narrow sense, is often viewed as a major culprit in this respect. The industry needs to educate and help its clients to differentiate between best value and lowest price.

Client Dissatisfaction

5. Under-achievement can also be found in the growing dissatisfaction with construction among both private and public sector clients. Projects are widely seen as unpredictable in terms of delivery on time, within budget and to the standards of quality expected. Investment in construction is seen as expensive, when compared both to other goods and services and to other countries. In short, construction too often fails to meet the needs of modern businesses that must be competitive in international markets, and rarely provides best value for clients and taxpayers.

6. The under-achievement of construction is graphically demonstrated by the City's view of the industry as a poor investment. The City regards construction as a business that is unpredictable, competitive only on price not quality, with too few barriers to entry for poor performers. With few exceptions, investors cannot identify brands among companies to which they can attach future value. As a result there are few loyal, strategic long-term shareholders in quoted construction companies.

7. Discussions with City analysts suggest that effective barriers to entry in the construction industry, together with structural changes that differentiated brands and improved companies' "quality of earnings" (i.e. stability and predictability of margins), could result in higher share prices and more strategic shareholders. We believe such a change towards stability of profit margins would be at least as highly valued by the City as a simple increase in margins.

The Client View

The British Property Federations 1997 survey of major UK clients reveals that:

- more than a third of major clients are dissatisfied with contractors' performance in keeping to the quoted price and to time, resolving defects, and delivering a final product of the required quality;
- more than a third of major clients are dissatisfied with consultants' performance in co-ordinating teams, in design and innovation, in providing a speedy and reliable service and in providing value for money.

A recent survey by the Design Build Foundation shows that:

- clients want greater value from their buildings by achieving a clearer focus on meeting functional business needs;
- clients' immediate priorities are to reduce capital costs and improve the quality of new buildings;
- clients believe that a longer-term, more important issue is reducing running-costs and improving the standard of existing buildings;
- clients believe that significant value improvement and cost reduction can be gained by the integration of design and construction.

Fragmentation

8. We recognise that the fragmentation of the UK construction industry inhibits performance improvement. One of the most striking things about the industry is the number of companies that exist – there are some 163,000 construction companies listed on the Department of the Environment, Transport and the Regions' (DETR) statistical register, most employing fewer than eight people.

9. We regard this level of fragmentation in construction both as a strength and a weakness:

- on the positive side, it is likely that it has provided flexibility to deal with highly variable workloads. Economic cycles have affected the industry seriously over past decades and have meant that it has been forced to concentrate more on survival than on investing for the future;
- on the negative side, the extensive use of subcontracting has brought contractual relations to the fore and prevented the continuity of teams that is essential to efficient working.

Building on Latham

10. It was the consequences of fragmentation which Sir Michael Latham principally examined in his landmark report published in 1994. The Task Force recognises that we are building on the firm foundations which Sir Michaellaid. We welcome the impact that his report has had on the industry and the developments arising from it, including the establishment of the Construction Industry Board and the recent legislation on adjudication and fair payment. Together with the Government's current initiative *Combating Cowboy Builders*, this will help to reform the way the industry does business and to counter the strongly ingrained adversarial culture.

11. In consequence, our view of UK construction is that, although it suffers from serious problems, the outlook is positive if action is taken quickly. Despite low levels of investment, falling employment and cyclical downturns, the industry's output has maintained a strong long term upward trend in real terms. Over the last forty years growth in real output has broadly matched GDP: Furthermore, labour productivity appears to have risen by more than 5% per year in real terms since 1981, faster than the average for the economy as a whole.

Promising Developments

12. We are also greatly encouraged by the wide range of promising developments which have emerged from the industry, its clients and its Government sponsors over the last few years, including:

- recent initiatives to improve construction performance, such as the Construction Round Table's "Agenda for Change", the Construction Clients' Forum's "Pact with the Industry" and the DETR's Construction Best Practice Programme;

- improved components, materials and construction methods, including standardisation and pre-assembly, and new technology such as 3D object-oriented modelling and global positioning systems;

- tools to tackle fragmentation, such as partnering and framework agreements, which are becoming increasingly used by the best firms in place of traditional contract-based procurement and project management;

- increasing interest in tools and techniques for improving efficiency and quality learned from other industries, including benchmarking, value management, teamworking, Just-In-Time, concurrent engineering and Total Quality Management.

Partnering

Partnering involves two or more organisations working together to improve performance through agreeing mutual objectives, devising a way for resolving any disputes and committing themselves to continuous improvement, measuring progress and sharing the gains. The Reading Construction Forum's best practice guides to partnering, 'Trusting the Team' and 'Seven Pillars of Partnering' demonstrate that where partnering is used over a series of construction projects 30% savings are common, and that a 50% reduction in cost and an 80% reduction in time are possible in some cases.

Tesco Stores have reduced the capital cost of their stores by 40% since 1991 and by 20% in the last two years, through partnering with a smaller supplier base with whom they have established long term relationships. Tesco is now aiming for a further 20% reduction in costs in the next two years and a 50% reduction in project time.

Argent, a major commercial developer, has used partnering arrangements to reduce the capitol cost of its offices by 33% and total project time in some instances by 50% since 1991. They partner with three contractors and a limited number of specialist sub-contractors, consultants and designers.

Standardisation and Pre-Assembly

Volumetric Ltd designs and manufactures prefabricated units which can be incorporated in a variety of buildings, including Forte's Travelodge, speculative housing and housing association developments, military accommodation, private hospitals and top of the range self-build houses. Advantages include speed of construction, lower cost, reduced need for skilled labour and achievement of zero defects.

McDonald's Restaurants have demonstrated an ability to construct a fully-functioning restaurant on site in 24 hours, using a very high degree of prefabrication and modularisation. The design allows expansion or even relocation

Performance Improvement Tools and Techniques

CALIBRE has been developed by BRE as a simple but effective system for mapping and understanding site processes and measuring and comparing on-site performance. Using hand-held computer technology feeding back to a lap top computer it provides real-time feedback to site managers to help them remove barriers to productivity, eliminate waste and improve value-adding activities

Value management is a structured method of eliminating waste from the brief and from the design before binding commitments are made. Value management is now used by up to a quarter of the construction industry to deliver more effective and better quality buildings, for example through taking unnecessary costs out of designs, and ensuring clearer understanding of the brief by all project participants and improving teamworking. Value management can also reduce costs by up to 10%

Benchmarking is a management tool which can help construction firms to understand how their performance measures up to their competitors' and drive improvement up to 'world class' standards. Taywood Engineering Ltd are using benchmarking in a project to identify a strategy for achieving zero defects in construction, including the principles of a 'zero defects culture' and a range a possible tools, such as the concept of a 'stop button' in site production, to prevent defects "going down the line".

Great Scope for Improvement

13. Leading clients working with the best construction companies are successfully combining many of these developments to achieve significant improvements in the cost, time and quality of projects. But there is plenty of scope for further improvement at the leading edge of the industry and for these improvements to be spread across the industry and offered to the vast majority of occasional and inexperienced clients. The Task Force is strongly of the view that there is nothing exceptional about what major clients are doing to improve performance in construction. Anybody can do it, given the time, the commitment and the resources.

Direction from Major Clients

14. In construction the need to improve is clear. Clients need better value from their projects, and construction companies need reasonable profits to assure their long-term future. Both points of view increasingly recognise that not only is there plenty of scope to improve, but they also have a powerful mutual interest in doing so. To achieve the performance improvements required there is a pressing need to draw all the promising developments in construction together and give them direction. The Task Force believes that this direction and the impetus for change must come from major clients. In the next section we, as representatives of major clients, set out the basis of this direction through our ambition to create a thoroughly modern construction industry.

CHAPTER 2

Our Ambition for UK Construction

15. The members of the Task Force were chosen for their expertise as construction clients and also for their extensive experience of other industries that have improved their performance. Dramatic changes have occurred in these industries over the last two or three decades driven largely by the customer and the need simply to survive the competition.

Improvements in Other Industries

16. In both manufacturing and service industries there have been increases in efficiency and transformations of companies which a decade or more ago nobody would have believed possible. For example, British grocery chains are now world leaders, the UK steel industry is a highly competitive international player, and car plants in this country are among the best internationally in terms of efficiency and productivity. And of course these successes come against a background of rising world-class standards – defects in the car industry are now measured in parts per million components rather than per hundred.

The Experience of Other Industries

Car Manufacturing

World-wide benchmarking studies of car and component manufacturing in the early 1990s revealed a two to one gap in performance and a 100 to one gap in quality between Japanese and Western car manufacturers. The opening of the Nissan, Toyota and Honda plants in the UK showed that this level of performance could also be achieved in plants outside Japan. Western car manufacturers then began crash programmes to implement "lean production" systems in order to close the gap. To fulfil their aim of 80% local content within a few years, the Japanese carmakers also began to work closely with local component suppliers to help them implement lean production.

The scale of the improvements achieved by the best and being sought by the others is impressive. The time to introduce a new car, from design freeze to launch, is coming down from 40 to 15 months. the time to weld, paint and assemble a car is coming down from 40 to 15 hours per car, with similar reductions in effort in component production. The rate of supplier defects delivered to the assembly pant is coming down from 3% to 5 parts per million. The time from placing an order on the factory to sale to a customer is coming down from 120 days to 15 days. As a result of these improvements UK car production and exports have nearly doubled over the last decade.

The most critical constraint on improvement lay in spreading lean production to smaller second tier suppliers. The Department of Trade and Industry sponsored initiatives to help smaller suppliers learn from Japan. In 1995 the leading manufacturers and suppliers established the "Industry Forum" as the focus for industry-wide improvement activities. The forum is unique in bringing together experienced engineers from Nissan, Honda, Toyota, General Motors and Volkswagen to train local engineers in accelerated process improvement on the shop floor in smaller component suppliers. They are also developing generic tools for spreading accelerated process improvement throughout the industry. After initial pump priming from the DTI the Forum will shortly become self-financing.

The Experience of Other Industries

Steel-making

The key drivers for the restructuring of British Steel were the need to respond to shareholders' and customers' simultaneous requirements for cost reduction and performance improvement, and the longer term need to secure the competitive position of steel compared with other materials such as concrete, plastic or aluminium. A series of complementary initiatives were introduced to deliver a dramatic and sustained improvement in performance.

Business procedures were revised, processes simplified and improved, and waste eliminated. A programme of Total Quality Management covering products, processes and employees throughout the Company was initiated, facilitating moves towards multi-skilling and teamworking. An essential enabler was and remains a substantial training programme: employees currently receive, on average, 11.4 training days each, representing a spend of 5% of employment costs. Capital investment was closely linked to customer requirements, productivity and quality improvements, and removal of bottlenecks.

Partnership arrangements with customers were put in hand to drive joint initiatives to take out cost and complexity, British Steel has taken steps to become involved at the design stage of customers' products, through broadening the Company's selling organisation to reach specifiers directly, and enhancing research and development facilities to facilitate joint working with customers. As a result of these initiatives British Steel has increased sales and production levels whilst reducing UK manpower from 200,000 to less than 40,000 in two decades. The programme has on ongoing objective of maintaining the competitive edge.

Grocery Retailing

Leading grocery producers and retailers established the Efficient Consumer Response (ECR) movement in the USA in 1993 to improve their competitiveness. The aim was to develop a common framework for jointly managing the grocery supply chain and to replace the advesarial relationships of the past. It was built around an industry 'scorecard' measuring the progress of all parties and a value chain costing methodoloy for identifying the savings being realised. In the UK ECR is co-ordinated by the Institute for Grocery Distribution, run jointly by the retailers and producers. Groups of ECR members undertook to carry out pilot projects together and to share the findings with the rest of the industry. Theses pilots were successful in demonstrating real savings that could only be achieved by working together, and led to new partnerships between producers and retailers.

ECR has spread right across the world and the UK industry is a leading player. In the last 15 years UK grocery retailers have made huge progress in streamlining their distribution systems, shrinking order lead times from two weeks to two days and cutting inventories from five to 2.5 weeks, at the same time as product ranges and volumes grew eight to ten fold. ECR has been instrumental in sustaining this rate of improvement across the whole supply chain and in breaking down adversarial relationships. It has also led to new cross-industry initiatives on standardisation, shared distribution arrangements and other issues.

Offshore Engineering

In 1992 the offshore oil and gas engineering industry in the North Sea faced a crisis. The price of oil dropped from $35 a barrel to $12, making exploitation uneconomic. Platform operators, contractors and suppliers came together to form the **C**ost **R**eduction **I**nitiative for the **N**ew **E**ra or CRINE, a co-operative effort to find ways of reducing wasteful activity in platform construction.

After 12 months of investigation and analysis the CRINE Report was published, recommending: functional rather than prescriptive specifications; common working practices; non-adversarial contracts and use of alliancing; reduction in procurement bureaucracy; and a single industry body for prequalification. These recommendations were put into practice by the industry. As a result the cost of oil and gas field developments was reduced by 40%.

The Experience of Other Industries

An unexpected result was the emergence of a network of innovative individuals committed to on-going co-operation for further improvement. By 1997 CRINE had been transformed into the CRINE Network, a continuous agent for change and a brand-name for cost reduction and competitiveness in the oil industry. Its vision is *"People working together to make the UK oil and gas industry competitive anywhere in the world by the year 2000"*. CRINE remains a model of "co-operative effort" in the supply chain which has been emulated and copied in many parts of the world. It has usefully been extended, through the ACTIVE Engineering Construction Initiative, to the UK's process plant industries, with a view to improving efficiency and enhancing competitiveness

Drivers of Change

17. We have looked at what has driven manufacturing and service industry to achieve these radical changes. We have identified a series of fundamentals to the process which we believe are just as applicable to construction as to any other business concern. These are:

- committed leadership: this is about management believing in and being totally committed to driving forward an agenda for improvement and communicating the required cultural and operational changes throughout the whole of the organisation.

  In construction, there is no part of the industry which can escape this requirement: it affects constructors, suppliers and designers alike. The Task Force has met many managers of companies in the construction industry over the last few months and, while many wish to improve company performance, we have yet to see widespread evidence of the burning commitment to raise quality and efficiency which we believe is necessary;

- a focus on the customer: in the best companies, the customer drives everything. These companies provide precisely what the end customer needs, when the customer needs it and at a price that reflects the products value to the customer. Activities which do not add value from the customer's viewpoint are classified as waste and eliminated.

  In the Task Force's experience, the construction industry tends not to think about the customer (either the client or the consumer) but more about the next employer in the contractual chain. Companies do little systematic research on what the end-user actually wants, nor do they seek to raise customers' aspirations and educate them to become more discerning. The industry has no objective process for auditing client satisfaction comparable with the 'ID Power survey' of cars or the 'Which' report. We think clients, both public sector and private sector; should be much more demanding of construction;

- integrate the process and the team around the product: the most successful enterprises do not fragment their operations - they work back from the customer's needs and focus on the product and the value it delivers to the customer. The process and the production team are then integrated to deliver value to the customer efficiently and eliminate waste in all its forms.

  The Task Force has looked for this concept in construction and sees the industry typically dealing with the project process as a series of sequential and largely separate operations undertaken by individual designers, constructors and suppliers who have no stake in the long term success of the product and no commitment to it. Changing this culture is fundamental to increasing efficiency and quality in construction.

- **a quality driven agenda:** Quality means not only zero defects but right first time, delivery on time and to budget, innovating for the benefit of the client and stripping out waste, whether it be in design, materials or construction on site. It also means after-sales care and reduced cost in use. Quality means the total package - exceeding customer expectations and providing real service.

  The industry rightly complains about the difficulty of providing quality when clients select designers and constructors on the basis of lowest cost and not overall value for money. We agree. But it must understand what clients mean by quality and break the vicious circle of poor service and low client expectations by delivering real quality.

- **commitment to people:** this means not only decent site conditions, fair wages and care for the health and safety of the work force. It means a commitment to training and development of committed and highly capable managers and supervisors. It also means respect for all participants in the process, involving everyone in sustained improvement and learning, and a no-blame culture based on mutual interdependence and trust.

  In the Task Force"s view much of construction does not yet recognise that its people are its greatest asset and treat them as such. Too much talent is simply wasted, particularly through failure to recognise the significant contribution that suppliers can make to innovation. We understand the difficulties posed by site conditions and the fragmented structure of the industry" but construction cannot afford not to get the best from the people who create value for clients and profits for companies.

18. We believe that these fundamentals together provide the model for the dramatic improvements in performance that UK construction must achieve if it is to succeed in the 21st century. Among many leading clients and construction companies this model is already being turned into reality, and is beginning to deliver dramatic improvements in the efficiency and quality of construction. We want to see this progress accelerated and spread to the rest of the industry and its clients.

Set targets for Improvement

19. To drive dramatic performance improvement the Task Force believes that the construction industry should set itself clear measurable objectives, and then give them focus by adopting quantified targets, milestones and performance indicators. This is evidently not the case at present. For example, it is not clear whether the construction industry is on target to meet Sir Michael Latham's aspiration to see a 30% improvement in productivity. In this respect, we welcome the work which the Construction Industry Board has now commenced on performance indicators.

20. If construction is to share in the benefits of improved performance the objectives and targets that it sets must be directly related to client's perceptions of performance. This means measures of improvement in terms of predictability, cost, time and quality. Clients will then be able to recognise increased value and reward companies that deliver it. Targets must also be set for improving the quality and efficiency of construction processes – in terms of safety and labour productivity for example. In this way corners are not cut and companies and their staff share in the benefits of success. In our experience this is the only way to make gains last and deliver continuous improvement.

Measure Progress

21. Construction must also put in place a means of measuring progress towards its objectives and targets. The industry starts with a clean sheet in this respect. It has a great opportunity to create an industry-wide performance measurement system which will enable clients to differentiate between the best and the rest, providing a rational basis for selection and to reward excellence.

22. In addition to objectives and targets, the Task Force would therefore like to see:

- the construction industry produce its own structure of objective performance measures agreed with clients;
- construction companies prepare comparative performance data and share it with clients and each other. The experience of other industries shows that this can be done without compromising legitimate needs for confidentiality;
- a system of independently monitored company 'scorecards', measuring companies' progress towards objectives and targets, instead of simple benchmarking. The names of the best performers would be made public and every company would be privately informed of where it stood in relation to its competitors.

The Scope for Improvement

23. To illustrate the kind of targets which the Task Force wants to see construction adopt we have set out in the table below our assessment of the minimum scope for improvement in the performance of UK construction. It is necessarily an impressionistic and partial assessment, since construction has no accepted performance indicators. Solid data on company and project performance in terms of efficiency and quality is hard to come by.

24. The scope for improvement that we have identified is underpinned by evidence from leading clients and construction companies from the UK and the USA. Indeed, we have taken a conservative view in most cases of what we know is being achieved by leading edge companies. We expect that the best UK construction companies and clients will meet these minimum rates of improvement in full and go on to surpass them.

25. Our assessment is also underpinned by what is known about the amount of waste in construction. Recent studies in the USA, Scandinavia and this country suggest that up to 30% of construction is rework, labour is used at only 40-60% of potential efficiency, accidents can account for 3-6% of total project costs, and at least 10% of materials are wasted. These are probably conservative estimates when compared to the amount of waste identified in manufacturing by best practice firms such as Toyota. Furthermore, an OECD study suggests that UK input costs are generally a third of those of other developed countries but output costs are similar or higher. The message is clear - there is plenty of scope for improving efficiency and quality simply by taking waste out of construction.

26. We have set our measures in terms of annual improvement. We expect construction to make dramatic initial increases in efficiency and quality, but in our experience greatest value is obtained through significant sustained improvement rather than one-off advances. We expect the leading companies in the industry to adopt these measures as targets, or similar ones of their own devising, to monitor them regularly and to report progress publicly – and that includes companies in all sections of the industry.

The Scope for Sustained Improvement		
Indicator	**Improvement per year**	**Current performance of leading clients and construction companies**
Capital cost All costs excluding land and finance.	Reduce by **10%**	Leading clients and their supply chains have achieved cost reductions of between 6 and 14% per ear in the last five years. Many are now achieving an average of 10% or greater per year.
Construction time Time from client approval to practical completion.	Reduce by **10%**	Leading UK clients and design and build firms in the USA are currently achieving reductions in to construction time for offices, roads, stores and houses of 10-15% per year.
Predictability Number of projects completed on time and within budget.	Increase by **20%**	Many leading clients have increased predictability by more than 20% annually in recent years, and now regularly achieve predictability rates of 95% or greater.
Defects Reduction in number of defects on handover.	Reduce by **20%**	There is much evidence to suggest that the goal of zero defects is achievable across construction within five years. Some UK clients and US construction firms already regularly achieve zero defects on handover.
Accidents Reduction in the number of reportable accidents.	Reduce by **20%**	Some leading clients and construction companies have recently achieved reductions in reportable accidents of 50-60% in two years or less, with consequent substantial reductions in project costs.
Productivity Increase in value added per head	Increase by **10%**	UK construction appears to be already achieving productivity gains of 5% a year. Some of the best UK and US projects demonstrate increases equivalent to 10-15% a year.
Turnover and profits Turnover and profits of construction firms.	Increase by **10%**	The best construction firms are increasing turnover and profits by 10-20% a year, and are raising their profit margins as a proportion of turnover well above the industry average.

Performance Improvement in Construction

- Tesco Stores have reduced the capital cost of their stores by 40% in five years. They are now targeting a further 20% reduction in costs over two years and a 50% reduction in project time.
- Argent have reduced the capital cost of office construction by 33% and total project time by 50% since 1991.
- BAA Pavement Team have reduced project time on airport runways and taxiways by more than 30%, reduced accidents by 50%, and achieved 95% predictability of cost and time in two years.
- The Whitbread Hotel Company have reduced construction time for its hotels by 40% since 1995 and costs have also been progressively reduced annually in real terms.
- Raynesway Construction Southern in a year have reduced the costs of maintaining Hampshire County Council's roads by 10%, increased turnover by 20& with the same labour force, and reduced accidents by 60%.
- The Neenan Company in Colorado have used 'lean construction' techniques over two years to reduce the time to produce a schematic design by 80% and project times and costs by 30%.
- Pacific Contracting of San Fransisco have used 'lean construction' to increase their productivity and turnover as a cladding and roofing subcontractor by 20% in eighteen months.
- Neil Muller Construction of South Africa have used Total Quality Management techniques to achieve an 18% increase in output per employee in a year, a 65% reduction in absenteeism in four years, and a 12% saving on construction time on a major project.

27. If the industry is not prepared to do this, the we propose that the clients should take the initiative. We are already aware of the Construction Round Table's an the Construction Clients' Forum's intentions in this respect and of the British Property Federations customer survey. We think it is essential that any comparative data takes account of user satisfaction with the buildings they occupy and with the services of the design and construction team.

Our ambition for UK Construction

28. This then is our ambition for a modern construction industry in the UK: adoption of the model of dramatic performance improvement that other industries have followed with such success, in order to deliver the challenging targets for increased efficiency and quality that we know are achievable. In the next section we offer the industry a practical approach to doing so, through the concept of the integrated project process.

CHAPTER 3

Improving the Project Process

29. Can construction learn from the successes of manufacturing and service industry? The Task Force believes it can. Our view is similar to that of construction industry representatives on the Task Force's visit to Nissan UK to see its advanced approach to production, who wrote:

"we see that construction has two choices: ignore all this in the belief that construction is so unique that there are no lessons to be learned; or seek improvement through re-engineering construction, learning as much as possible from those who have done it elsewhere"

30. If we follow the latter approach, what is it that construction has to learn to do differently ? We believe that at least part of the answer is that the industry has to rethink the process through which it delivers its projects with the aim of achieving continuous improvement in its performance and products.

Repeated Processes

31. We have repeatedly heard the claim that construction is different from manufacturing because every product is unique. We do not agree. Not only are many buildings, such as houses, essentially repeat products which can be continually improved but, more importantly, the process of construction is itself repeated in its essentials from project to project. Indeed, research suggests that up to 80% of inputs into buildings are repeated. Much repair and maintenance work also uses a repeat process. The parallel is not with building cars on the production line; it is with designing and planning the production of anew car model.

32. The Task Force has looked at what leading clients and innovative constructors both here and overseas are doing to rethink the construction process. We have been informed by our own experience and have tested out ideas with our own construction supply chains. The documentary evidence is scattered at present but there are a number of pointers which indicate the same direction. These include, for example BSRIA's study of the installation of building services in office buildings and the Genesis project undertaken by BAA with support from BRE. Both studies confirmed that as much as 40% of the manpower used on construction sites can be wasted.

33. These and other studies all suggest that there are significant inefficiencies in the construction process and that there is potential for a much more systematised and integrated project process in which waste in all its forms is significantly reduced and both quality and efficiency improved. This ties in with our observation that manufacturing has achieved performance improvements by integrating the process and team around the product.

An Integrated Project Process

34. If we are to extend throughout the construction industry the improvements in performance that are already being achieved by the best, we must begin by defining the integrated project process. It is a process that utilises the full construction team, bringing the skills of all the participants to bear on delivering value to the client. It is a process that is explicit and transparent, and therefore easily understood by the participants and their clients.

35. The rationale behind the development of an integrated process is that the efficiency of project delivery is presently constrained by the largely separated processes through which they are generally planned, designed and constructed. These processes reflect the fragmented structure of the industry and sustain a contractual and confrontational culture.

36. The conventional construction process is generally sequential because it reflects the input of designers, constructors and key suppliers. This process may well minimise the risk to constructors by defining precisely, through specifications and contracts, what the next company in the process will do. Unfortunately, it is less clear that this strategy protects the clients and it often acts as an effective barrier to using the skills and knowledge of suppliers and constructors effectively in the design and planning of the projects.

37. Moreover, the conventional processes assume that clients benefit from choosing anew team of designers, constructors and suppliers competitively for every project they do. We are far from convinced of this. The repeated selection of new teams in our view inhibits learning, innovation and the development of skilled and experienced teams. Critically, it has prevented the industry from developing products and an identity - or brand - that can be understood by its clients.

Focus on the End Product

38. The Task Force believes that construction can learn from other sectors of the economy in tackling these problems by focusing the construction process on delivering the needs of the end-user or consumer through the end product. Most clients for construction are interested only in the finished product, its cost, whether it is delivered on time, its quality and functionality. Concentrating on the needs of the consumer leads to a view of construction as a much more integrated process.

39. Our experience is that the overall process can be subdivided into four complementary and interlocked elements:

- product development
- project implementation
- partnering the supply chain
- production of components

40. The key premise behind the integrated project process is that teams of designers, constructors and suppliers work together through a series of projects, continuously developing the product and the supply chain, eliminating waste in the delivery process, innovating and learning from experience. Many major and experienced clients are already doing this through their partnering arrangements and are achieving the levels of performance improvement that we have targeted earlier in this report. The challenge for the construction industry is to develop their own integrated teams to deliver the same benefits to occasional and inexperienced clients. The Task Force believes that this is not only desirable but wholly possible.

Product Development

41. Product development is the means of continuously developing a generic construction product – for example, a house, a road, an office or a repair and maintenance service – to meet and inform the needs of clients and consumers. It requires a detailed knowledge of clients and their aspirations, and effective processes for innovating and for learning through objective measurement of completed projects. The Task Force see this activity as parallelling the sort of research into the needs of customers undertaken by most other industries.

Product Development

- Listening to the voice of the consumer and understanding their needs and aspirations.
- Developing products that will exceed client expectations.
- Defining the attributes of a construction product and understanding how they are influenced through specific engineering systems and components.
- Defining projects that deliver the product in specific circumstances and setting clear targets for the project of delivery teams.
- Assessing completed projects and customer satisfaction systematically and objectively, and feeding the knowledge gained back into the product development process.
- Innovating with suppliers to improve the product without loss of reliability,

42. Product development requires continuity from a dedicated product team: one with product design skills, with close links to the supply chain through which the skills of suppliers and their innovations can be assessed, and with access to relevant market research. Many major and experienced clients already have organisations dedicated to developing their own construction products and the construction industry is beginning to develop similar teams in response to the opportunities presented by the Private Finance Initiative. Again, there is a need to devise means of making these arrangements available to all clients.

Project Implementation

43. Project implementation is about translating the generic product into a specific project on a specific site for a specific customer. The implementation team, incorporating all of the key suppliers, needs to work together to design the engineering systems, select key components and pre-plan the manufacture, construction and commissioning. The Task Force would like to see this approach being backed by the use of computer modelling to test the performance of the end-product for the customer and, especially, to minimise the problems of construction on site. Our feeling is that good IT is an essential part of improving the efficiency of construction.

44. We see more effective project implementation as being one of the keys which can unlock greater efficiency on site, arising from, for example, using standardised components, precise engineering fit and the use of extensive pre-assembly. We also believe this will significantly improve quality. However, the delivery of such an approach has, in our experience, revealed a culture gap. Site construction needs to be carried out by a relatively small dedicated team of multi-skilled operatives who develop their expertise over a series of projects. We consider such cultural implications further in the next chapter.

Project Implementation
• Leadership of an integrated team of suppliers, constructors and designers dedicated to engineering and constructing the project.
• Mapping of processes, measurement of performance and continuous improvement to improve quality and eliminate waste.
• Development of engineering systems and selection of components to achieve product performance targets.
• Pre-planning of manufacture, construction and commissioning.
• Assembly of components and sub-assemblies on site and commissioning of the completed project.
• Training and development of all participants to support improvements in performance.
• Learning from experience and feedback into the project delivery process.

Partnering the Supply Chain

45. The Task Force envisages a very different role for the construction supply chain. In our view, the supply chain is critical to driving innovation and to sustaining incremental and sustained improvement in performance. Partnering is, however, far from being an easy option for constructors and suppliers. There is already some evidence that it is more demanding than conventional tendering, requiring recognition of interdependence between clients and constructors, open relationships, effective measurement of performance and an ongoing commitment to improvement. For example, the Ministry of Defence/DETR “Building down Barriers” project is supported by the Tavistock Institute whose hob it has been to help the project participants unlearn the traditional relationships between constructors themselves and with their clients. An essential aspect of partnering is the opportunity for participants to share in the rewards of improved performance.

Project Implementation
• Acquisition of new suppliers through value-based sourcing.
• Organisation and management of the supply chain to maximise innovation, learning and efficiency.
• Supplier development and measurement of suppliers’ performance.
• Managing workload to match capacity and to incentivise suppliers to improve performance.
• Capturing suppliers’ innovations in components and systems.

Production of Components

46. There is no reason why constructions’ approach to component production should be radically different from that used by today’s leading manufacturers of consumer products. It should involve the detailed planning, management and sustained improvement of the production process to eliminate waste and ensure the right components are produced and delivered at the right time, in the right order and without any defects. The Task Force believes that construction has a great deal to learn about effective logistics management: the industry would do well to study the experience of the retail and distribution industries and vehicle manufacturing in this respect.

Production of Components
• Detailed engineering design of components and sub-assemblies.
• Planning, management and continuous improvement of the production process.
• Development of a range of standard components which are used in most projects
• Production of components and sub-assemblies to achieve ‘right first time’ quality.
• Management of the delivery of components and sub-assemblies to site exactly when needed
• Measurement of the performance of completed components and systems.
• Learning from experience about product performance and durability.
• Innovation in the design of components to improve construction products.

47. Component production also includes the sustained commitment to innovation in the design of components, and development of a range of standard components which are used in most projects. By working closely with the product development teams component manufacturers can push forward the boundaries of client aspirations. The construction industry very often fails to educate the client about what improvements in products are available and this is an especially serious omission when dealing with smaller clients who are naturally less familiar with what is available.

Sustained Improvement

48. Once the integrated project process has been put in place the next step is to maintain the momentum of the increases in efficiency and quality that it offers. The key to this is to implement a programme of sustained improvement of the construction process to eliminate waste and increase the value that it adds to the client. Again the Task Force has turned to other industries with experience of success in this area for guidance.

49. We have investigated the emerging business philosophy of "lean thinking" which has been developed first in the car industry and is now spreading through the best manufacturers and into retailing and other industries. Lean thinking presents a powerful and coherent synthesis of the most effective techniques for eliminating waste and delivering significant sustained improvements in efficiency and quality.

50. We are impressed by the dramatic success being achieved by leading companies that are implementing the principles of "lean thinking" and we believe that the concept holds much promise for construction as well. Indeed, we have found that lean thinking is already beginning to be applied with success by some construction companies in the USA. We recommend that the UK construction industry should also adopt lean thinking as a means of sustaining performance improvement.

What is Lean Thinking?

Lean Production is the generic version of the Toyota Production System, recognised as the most efficient production system in the world today. Lean Thinking describes the core principles underlying this system that can also be applied to every other business activity – from designing new products and working with suppliers to processing orders from customers.

The starting point is to recognise that only a small fraction of he total time and effort in any organisation actually adds value for the end customer. By clearly defining **value** for a specific product or service from the end customer's perspective all the non value activities, often as much as 95% of the total, can be targeted for removal step by step.

Few products or services are provided by one organisation alone, so that waste removal has to be pursued throughout the whole **value stream** – the entire set of activities across all firms involved in jointly delivering the product or service. New relationships are required to eliminate inter-firm waste and to manage the value stream as a whole.

Instead of managing the workload through successive departments, process are reorganised so that the product design flows through all the value adding steps without interruption, using the toolbox of lean techniques to successively remove the obstacle to **flow**. Activities across each firm are synchronised by **pulling** the product or design from upstream steps just when required in time to meet the demand from the end customer.

Removing wasted time and effort represents the biggest opportunity for performance improvement. Creating flow and pull starts with radically reorganising individual process steps, but the gains become truly significant as all the steps link together. As this happens more and more layers of waste become visible and the process continues towards the theoretical end point of **perfection**, where every asset and every action adds value for the end customer. Lean Thinking represents a path of sustained performance improvement and not a one-off programme.

Applying Lean Thinking in Construction

Pacific Contracting of San Fransisco, a specialist cladding and roofing contractor, have used the principles of *lean thinking* to increase their annual turnover by 20% in 18 months with the same member of staff. The key to this success was improvement of the design and procurement process in order to facilitate construction on site, investing in the front end of projects to reduce costs and construction times. They identified two major problems to achieving flow in the whole construction process – inefficient supply of materials which prevented site operations from flowing smoothly, and poor design information from the prime contractor which frequently resulted in a large amount of redesign work.

To tackle these problems Pacific Contracting combined more efficient use of technology with tools for improving planning of construction processes. They use a computerised 3D design system to provide a better, faster method of redesign that leads to better construction information. Their design system provides a range of benefits, including isometric drawings of components and interfaces, fit co-ordination, planning of construction methods, motivation of work crews through visualisation, first run tests of construction sequences and virtual walk-throughs of the product. They also use a process planning tool known as Last Planner, developed by Glen Ballard of the Lean Construction Institute, to improve the flow of work on site through reducing constraints such as lack of materials or labour.

Applying Lean Thinking in Construction

The Neenan Company, a design and build firm, is one of the most successful and fastest growing construction companies in Colorado. The firm has worked to understand the principles of lean thinking and look for applications to its business, using ‘Study Action Teams’ of employees to rethink they way they work. Neenan’s have reduced project times and costs by up to 30%, through developments such as:

- Improving the flow of work on site by defining units of production and using tools such as visual control processes;
- Using dedicated design teams working exclusively on one design from beginning to end and developing a tool known as ‘Schematic Design in a Day’ to dramatically speed up the design process;
- Innovating in design and assembly, for example through the use of pre-fabricated brick infill panels manufactured off site and pre-assembled atrium roofs lifted into place;
- Supporting sub-contractors in developing tools for improving processes.

CHAPTER 4

Enabling Improvement

51. Substantial changes in the culture and structure of UK construction are required to enable the improvements in the project process that will deliver our ambition of a modem construction industry. These include changes in working conditions, skills and training, approaches to design, use of technology and relationships between companies.

52. The Task Force believes that, to deliver the cultural changes necessary to improve the project process, we must start by valuing our people. Not only is the quality of the workforce fundamental to the process of change in construction, but also the way workers are treated. In our view, the workforce is undervalued, under-resourced and frequently treated as a commodity rather than the industry's single most important asset.

Decent Working Conditions

53. Some of the changes we are looking for may take time to achieve. Others can be delivered almost instantly. For example, the facilities which are available to workers on site are typically appaling. Clients and their customers do not like the poor image of the industry in this respect any more than does the industry itself. It does not require a big step to provide workers with uniforms, proper facilities and rest areas. Construction sites themselves should become advertisements for the industry and the firms working on them.

Improving Conditions on Site

As part of its *Building for the Future* initiative Tesco Stores has introduced visitor centres, on-site canteens, changing rooms and showers on its sites. Construction materials are stored in warehouses on site, reducing losses from theft and damage. Site branding has been introduced – all Tesco sites have identical blue hoardings and workers on them wear branded overalls with both Tesco and their employer's name. The increased team spirit and commitment engendered by these simple innovations have contributed to Tesco's achievement of a 40% reduction in construction costs.

54. The health and safety record of construction is the second worst of any industry. We have observed that most accidents seem to occur when people are either not properly trained or working out of process. The Task Force has asked the Health and Safety Executive to comment on our provisional targets for improvement, published in February. Their advice was to ask the industry to reflect not only on the purely welfare consequences of a poor health and safety record but to consider as well its cost in terms of lost work days, potential prosecutions and, in extreme cases, the enforced closure of construction sites.

More and Better Training

55. We have posed the question whether construction has the right skills to improve productivity. Our view is that there are significant gaps:

- at the top management level, there is a shortage of people with the commitment to being best in class and with the right balance of technical and leadership skills to manage their businesses accordingly. The industry needs to create the necessary career structure to develop more leaders of excellence;

- at the project manager level, we see a need for training in integrating projects and leading performance improvement, from conception to final delivery. We invite training organisations, including the professional institutions, to develop the necessary training programmes;

- the key grade on site is the supervisor. The UK has one of the highest levels of supervision on site internationally but one of the poorest records of training for supervisors. We invite the Construction Industry Training Board and other relevant National Training Organisations to consider this issue as a matter of urgency;

- among designers the high standards of professional competence achieved in their training and development need to be matched by a more practical understanding of the needs of clients and of the industry more generally. They need to develop greater understanding of how they can contribute value in the project process and the supply chain;

- there is not enough multi-skilling. The experience of other industries is that heavily compartmentalised, specialist operations detract from overall efficiency. Modern building techniques require fewer specialist craftsmen but more workers able to undertake a range of functions based around processes rather than trade skills. This is being addressed by overseas companies but the UK is in danger of being left behind;

- upgrading, retraining and continuous learning are not part of construction's current vocabulary. There is already frustration amongst component suppliers that their innovations are blocked because construction workers cannot cope with the new technologies that they are making available. This has to change.

56. Training and quality are inextricably interlinked. The experience of Task Force members is unequivocally that quality will not improve and costs will not reduce until the industry educates its workforce not only in the skills required but in the culture of teamwork. We invite the employers and the National Training Organisations to work with Government to put together an agenda for urgent action on this issue.

57. In our view, training will only be given the emphasis it deserves if all major clients, including the public sector, give preference to constructors who can demonstrate that they use trained workers. One way of achieving this is for major clients to insist that workers hold valid cards under the Construction Skills Certification Scheme. We would like to see this valuable scheme extended and use made of smart card technology to discourage the employment of workers who do not have the appropriate qualifications.

Design for Construction and Use

58. As we have already emphasised, in our experience too much time and effort is spent in construction on site, trying to make designs work in practice. The Task Force believes that this is indicative of a fundamental malaise in the industry - the separation of design from the rest of the project process. Too many buildings perform poorly in terms of flexibility of use, operating and maintenance costs and sustainability. In our view there has to be a significant re-balancing of the typical project so that all these issues are given much more prominence in the design and planning stage before anything happens on site. In other words, design needs to be properly integrated with construction and performance in use. Time spent in reconnaissance is not wasted.

59. There is a series of practical consequences that flows from this:

- suppliers and subcontractors have to be fully involved in the design team. In manufacturing industry, the concept of "design for manufacture" is a vital part of delivering efficiency and quality, and construction needs to develop an equivalent concept of “design for construction”;

- the experience of completed projects must be fed into the next one. With some exceptions the industry has little expertise in this area. There are significant gains to be made from understanding client satisfaction and capturing technical information, such as the effectiveness of control systems or the durability of components;

- quality must be fundamental to the design process. Defects and snagging need to be designed out on the computer before work starts on site. ‘Right first time’ means designing buildings and their components so that they cannot be wrong;

- designers should work in close collaboration with the other participants in the project process. They must understand more clearly how components are manufactured and assembled, and how their creative and analytical skills can be used to best effect in the process as a whole. There is no longer a place for a regime of design fees based on a percentage of the costs of a project, which offers little incentive to build efficiently;

- design needs to encompass whole life costs, including costs of energy consumption and maintenance costs. Sustainability is equally important. Increasingly, clients take the view that construction should be designed and costed as a total package including costs in use and final decommissioning.

- clients too must accept their responsibilities for effective design. Too often they are impatient to get their project on site the day after planning consent is obtained. The industry must help clients to understand the need for resources to be concentrated up-front on projects if greater efficiency and quality are to be delivered.

Standardisation

60. Standardisation also has an important role to play in improving the design stage of construction. The average car contains about 3,000 components. A house, by comparison, has about 40,000. We see a useful way of dealing more efficiently with the complexity of construction is to make greater use of standardised components. We call on clients and designers to make much greater use of standardised components and measure the benefits of greater efficiency and quality that standardisation can deliver.

61. There is also much scope for standardising processes. This can provide much greater predictability about what is performed, by whom, how and when. Standardisation of processes and components need not result in poor aesthetics or monotonous buildings. We have seen that, both in this country and abroad, the best architects are entirely capable of designing attractive buildings that use a high degree of standardisation.

The Scope for Standardisation

The Construction Confederation in its evidence to the Task Force told us there was scope to standardise many construction products and components. Examples include:

- Manhole covers – local authorities have more than 30 different specifications for standard manhole covers;
- Doors – hundreds of combinations of size, veneer and ironmongary exist;
- Motorway bridges – many UK bridges are prototypes, whereas they are of standard construction in France, Germany, and Belgium;
- Toilet pans – there are 150 different types in the UK but only six in the USA;
- Lift cars – although standard products are available, designers almost invariably wish to customise these.

The Confederation cites the benefits of standardisation as being: reductions in manufacturing costs; fewer interface and tolerance problems; shorter construction periods; and more efficient research and development of components.

Technology as a Tool

62. The Task Force does not consider that technology on its own can provide the answer to the need for greater efficiency and quality in construction. There have been celebrated examples of new technology being used to reinforce outdated and wasteful processes – and it does not work. The advice offered to construction by leading manufacturing industries is to approach change by first sorting out the culture, then defining and improving processes and finally applying technology as a tool to support these cultural and process improvements.

63. Members of the Task Force have seen the effectiveness of this approach for themselves on European housing sites that are using innovative forms of building, together with a high degree of prefabrication, pre-assembly and standardisation. What surprised us was that, when asked for the source of efficiency savings on site, the constructors and developers tended not to attribute them to the technology of construction but to pre-planning with suppliers and component manufacturers to minimise the time actually spent on site.

64. One area in which we know new technology to be a very useful tool is in the design of buildings and their components, and in the exchange of design information throughout the construction team. There are enormous benefits to be gained, in terms of eliminating waste and rework for example, from using modern CAD technology to prototype buildings and by rapidly exchanging information on design changes. Redesign should take place on computer, not on the construction site.

Better Regulation

65. We accept that a framework of regulatory controls in construction and development is entirely necessary, and indeed can help to produce efficiency and quality. But, in our view the interpretation and application of regulations is inconsistent across the country, making it more difficult to implement a construction project speedily and efficiently. Significant costs and delays are often incurred in the design and planning of projects by the variability of enforcement of regulations, and by duplication of processes between agencies.

66. We invite central and local Government to look carefully at ways of achieving better regulation. In particular, we feel that there is scope for regulatory regimes such as building control to be more output driven, so that constructors and their clients are able to deliver to performance standards rather than detailed prescriptions. We are also of the view that making the processes of the land use planning system more predictable would help improve the efficiency of construction, particularly housebuilding. We look to Lord Rogers' task force on urban regeneration to consider this issue.

Long Term Relationships

67. An essential ingredient in the delivery of radical performance improvements in other industries has been the creation of long term relationships or alliances throughout the supply chain on the basis of mutual interest. Alliances offer the co-operation and continuity needed to enable the team to learn and take a stake in improving the product. A team that does not stay together has no learning capability and no chance of making the incremental improvements that improve efficiency over the long term. The concept of the alliance is therefore fundamental to our view of how efficiency and quality in construction can be improved and made available to all clients, including inexperienced ones.

68. We have already mentioned the need for long term relationships in construction in the previous section where we discussed partnering the supply chain. Partnering on a series of projects is a powerful tool increasingly being used in construction to deliver valuable performance improvements. We are proposing that the industry now goes a stage further and develops long-term alliances that include all those involved in the whole process of delivering the product, from identification of client need to fulfilment of that need.

Long Term Relationships

The Whitbread Hotel Company rationalised its supply chain from 30 contractors to 5 and embarked on long-term partnership arrangements. Working on the basis of mutual interest, a construction strategy, objectives and improvement targets are set through negotiation between Whitbread, its partners and the supply chain. whitbread shares its five year business plan with its partners so that they contribute proactively to the achievement of Whitbread's objectives whilst planning their own businesses with greater effectiveness. Whitbread agrees fixed amounts for contractors' profits and overheads and shares savings from performance improvement with its partners. Competition within the supply chain focuses upon delivering continually improving performance.

69 In this connection, the Task Force wishes to see:

- new criteria for the selection of partners. This is not about lowest price, but ultimately about best overall value for money. Partnering implies selection on the basis of attitude to teamworking, ability to innovate and to offer efficient solutions. We think that it offers a much more satisfying role for most people engaged in construction;

- all the players in the team **sharing in success** in line with the value that they add for the client. Clients should not take all the benefits: we want to see proper incentive arrangements to enable cost savings to be shared and all members of the team making fair and reasonable returns;

- **an end to reliance on contracts.** Effective partnering does not rest on contracts. Contracts can add significantly to the cost of a project and often add no value for the client. If the relationship between a constructor and employer is soundly based and the parties recognise their mutual interdependence, then formal contract documents should gradually become obsolete. The construction industry may find this revolutionary. So did the motor industry, but we have seen non-contractually based relationships between Nissan and its 130 principal suppliers and we know they work;

- the introduction of **performance measurement** and competition against clear targets for improvement, in terms of quality, timeliness and cost, as the principal means of sustaining and bringing discipline to the relationships between clients, project teams and their suppliers. The evidence we have seen is that these relationships, when conducted properly, are much more demanding and rewarding than those based on competitive tendering. There are important issues here, particularly for the pubic sector.

Replacing Contracts with Performance Measurement

Nissan UK and Tallent Engineering Ltd have no formal contract beyond an annual negotiation of the cost and quality of the rear axles that Tallent produce for Nissan's cars, and rigorous targets for improving performance. Each morning Tallent receives an order from Nissan detailing the precise mix of axles required by Nissan and five times a day Tallent deliver to Nissan's Sunderland plant. If a problem was to occur with quality Tallent would send engineers to Nissan to fix it on the car production line. If a problem resulted in a significant loss of production, Nissan would expect to compensate Tallent for lost business or vice versa, but this has never happened and both sides work hard to ensure it cannot. Both Nissan and Tallent use similar no-contracts relationships with the firms delivering their construction projects.

Nissan's QCDDM supply chain management system is acknowledged to be among the most effective in the world. It measures all suppliers on **Q**uality, **C**ost, **D**elivery, **D**esign and **M**anagement against negotiated continuous improvement targets. For each element the supplier is marked on a range of product and process items which are aggregated on a weighted basis to give a performance percentage for that element. Competition is created across the supply chain by collating the performance information every month and informing each supplier of its performance in relation to the others.

70. Such relationships inevitably require mutual interdependence, some continuity in workflow and, if not stability, at least greater predictability. The Task Force recognises that this can be difficult for the construction industry. It is also potentially difficult for many clients. However, experience suggests that long term satisfactory partnering arrangements themselves generate greater continuity in workload, and this may be especially true in a construction industry in which an increasing premium is being placed by clients on quality.

Reduced Reliance on Tendering

71. The most immediately accessible savings from alliances and partnering come from a reduced requirement for tendering. Whilst this may go against the grain, especially for the public sector, it is vital that away is found to modify processes so that tendering is reduced. Clients may well ask how they can be satisfied that they are getting value for money. The answer lies in comparison between suppliers and rigorous measurement of their performance. With quantitative performance targets and open book accounting, together with demanding arrangements for selecting partners, the Task Force believes that value for money can be adequately demonstrated and properly audited. We invite the Treasury, with DETR, to consider the appropriate mechanisms further and give guidance to public bodies.

72. The radical changes required in the culture of the construction industry are likely to mean that there will be fewer but bigger winners. The Task Force's view is that those companies with the right culture deserve to thrive. Cut-throat price competition and inadequate profitability benefit no-one. For the sake of the long-term health of the industry and its clients we wish to see a culture of radical and sustained improvement in performance enabled in UK construction.

CHAPTER 5

Improving House building

73. As part of its terms of reference the Task Force was asked to look particularly at improving the efficiency and quality of housing construction. Whilst the Task Force considers that the scope for improving performance is as great in housing development as in other forms of construction, we believe that there should be specific initiatives to encourage advances in this sector. In our view housebuilding is affected by some significant factors that distinguish it from other sectors of the construction industry:

- housing development operates within a regulatory environment, affecting the level and location of activity. There are some in-built inefficiencies within the process which arise from the present requirements of the planning system;
- land prices have a major impact on out turn costs, representing up to 50% of total costs in some areas. These are a function of demand rather than of efficiency;
- in the private housing market demand by a 'one-off' disaggregated client base is dictated as much by price and location as by quality of the housing product or the efficiency of its performance;
- in the social housing sector, demand by corporate clients {housing associations and local authorities) is affected by uncertainties and inefficiencies resulting from periodic changes in policy direction and unpredictable levels of investment.

Promising Developments

74. There are promising developments in both private and public sector housing in the UK, although most innovatory housebuilding is being undertaken overseas. Good quality public housing, indistinguishable from the housing for sale that it is increasingly located alongside, is becoming commonplace. In the social housing sector the main corporate clients are increasingly investigating innovative approaches to housebuilding which offer significant improvements in the speed and cost of construction while retaining high quality.

75. In the social housing sector housing associations are the dominant providers of new housing. In 1998/99 they expect to start schemes {both new build and rehabilitation) worth around £2 billion for approximately 30,000 homes. 60 housing associations account for some 50% of these schemes. The sector, including both housing associations and local authorities, also faces a growing demand for repairs and maintenance.

76. The Task Force believes that the main initial opportunities for improvements in housebuilding performance exist in the social housing sector for the simple reason that most social housing is commissioned by a few major clients. However, we would expect improved practice in developing social housing to affect expectations and activity in the wider housing market. Consequently we see much scope for cross-fertilisation of innovation between the public and private sectors.

Developments in Housebuilding

Westbury Homes are actively pursuing an innovation approach to housing. They are developing new customer-focused approaches to develop products which will enable them to expand into new markets. They are trailing new component systems and production processes in demonstration projects and they are developing partnering arrangements with their suppliers. Both Wimpey Homes and Westbury have brought in board-level expertise from manufacturing industry in order to implement new supply-chain management techniques.

Over the last three years Bovis Homes, like many volume housebuilders, has standardised its product by using standard plan forms built from bulk-purchased parts. The standard house types are regularly re-engineered by the product development team in response to feedback from the sales and marketing team and customers. Research into what the customer wants is continually carried out using questionnaires, and value for different types of customer is defined in terms of price, locality, number of rooms, appearance, and quality of construction. A full customer care service is also provided.

Housing associations such as Southern Housing Group, Peabody, Hyde Housing Association and Guiness Trust are implementing lessons from abroad to improve the procurement of low-cost, high quality adaptable housing. For example, the Dutch Open Building approach is being demonstrated, offering tenants a wider range of choices of internal fit-out in both new-build and refurbishment schemes. Modular industrialised housing systems such as those used in Japan by Sekisui and Toyota are being trailed to reduce the cost and time of construction and provide tight quality control. This can deliver housing with zero defects on-site, removing the need for expensive and time-consuming 'snagging' and 'making good'.

Leading suppliers in the social housing market, such as Willmott Dixon, have initiated their own innovation strategies aimed at delivering greatly improved products and services to housing associations. Component manufacturers like Redland and Hepworth are also investing heavily in R&D to develop better component systems to speed up construction.

Potential for Change

77. In support of the Task Force's work programme and as part of a wider programme of meetings to test our thinking, the Housing Corporation organised seminars to which representatives of some of the major housing associations and housing construction companies were invited. They offered a useful opportunity to assess the potential for radical change. These events highlighted:

- an enthusiasm amongst both housing associations, as clients, and contractors for the pursuit of greater efficiency and quality;
- the vital influence of clients over the performance of the housebuilding industry. Well informed, demanding clients who know what they want and how much they are prepared to pay for it, and are able to specify their requirements clearly, are an essential pre-requisite to the achievement of a modern, efficient, world-class housebuilding industry;
- the belief that sustained improvement in the industry can only be achieved if rigorous targets are set and performance measured on a consistent basis;
- the fact that to achieve step improvements in innovation, standardisation of components and cost efficiency, more can be achieved by co-operation between clients, constructors and suppliers than through competition.

A Housing Forum

78. The conclusion of these seminars was that a forum of major developing housing associations and the major housebuilding and construction firms could act as the catalyst for change. The Task Force proposes the setting up of such a forum to take forward the agenda. We would see the main objectives of this body to be to bring together those clients, contractors and suppliers committed to performance improvement to:

- agree targets for improvement, performance indicators, and arrangements for data collection, analysis and dissemination;
- establish principles for commissioning and evaluating innovative demonstration projects and disseminating good practice;
- simplify procurement processes, streamline supply chains and standardise component linkages;
- encourage long term partnering arrangements between clients and providers to secure consistency, continuity, innovation and value for money.

Government Support

79. Although it would be for the members of the forum to agree a way forward, pro-active s support and encouragement from Government will also be essential. The Task Force sees this as taking three forms:

- pump priming contributions to support a secretariat for the forum. We feel that DETR and the Housing Corporation should partly support the secretariat costs of the forum, alongside membership fees from client and construction companies;
- capital funding for demonstration projects. The government should establish within the Housing Corporation's Approved Development Programme an allocation for demonstration projects. We suggest £10 million. This, when matched with private finance will support a programme of innovative development totalling some £20 million per annum;
- prioritising those investment projects offering improved value for money. In the longer term if the forum is successful, it should result in a range of lower cost, more innovative, better value homes. These should routinely receive high priority in the allocation of future public investment, thereby reinforcing the impetus for continuous improvement.

80. Housebuilders and their clients need to share experience of innovation. However, the key ingredient for success in achieving significant improvements in the quality and efficiency of housebuilding will be the commitment of those involved. In this housebuilding shares the same ground as the rest of UK construction.

CHAPTER 6

The Way Forward

81. The Task Force believes that the way forward to achieving the ambition of a modern construction industry lies in **commitment**. We are calling for:

- **commitment from major clients** to fulfil their responsibility to lead the implementation of our agenda for dramatically improving the efficiency and quality of construction;

- **commitment from the construction industry** to work with major clients to deliver the significant performance improvements that are possible, and offer these to the occasional and inexperienced clients; and

- **commitment from Government** to create and sustain the environment that is needed to enable dramatic improvements in construction performance, and encourage the public sector to become best practice clients.

Demonstration Projects

82. The major clients represented on the Task Force have agreed to take the lead and demonstrate their own commitment to improving performance by undertaking demonstration projects to develop and illustrate the ideas that we have set out. However, we do not want this to be an exclusive exercise: we invite other major private and public sector clients of the construction industry, together with the constructors, designers and suppliers that work with them, to offer similar projects on which together we can test and develop innovation. Our ambition is to make a start with at least £500 million worth of projects.

83. We propose that this core of projects and the housebuilding forum should become the basis of a movement for change and innovation in construction, established to pool experience among major clients and construction companies, develop ideas and drive improvement in quality and efficiency. We see such a movement as the principal way in which the construction industry can gain benefit from the lead being given by the major clients and grasp the initiative itself.

A Movement for Change

84. We envisage the movement for change as a group of people, possibly supported by a secretariat, who are committed to improving the delivery of their projects and the performance of their companies by applying the ideas that the Task Force has set out. The movement would be a network through which members could collaborate with each other in developing construction techniques and skills and exchanging ideas for increasing efficiency and quality. The movement should be open to all who are able to demonstrate commitment to:

- carrying out demonstration projects to advance the knowledge and practice of construction best practice;

- focusing on the needs of their clients in everything that they do;

- developing within their own organisations and throughout their supply chains a culture of trust and respect that encourages the contributions of all participants in the project process;
- training all their staff fully and providing them with conditions of employment and facilities that enable them to give of their best;
- measuring performance against other member's projects and project processes, and sharing the results with the wider industry;
- extending the benefits of improved performance to all their clients.

Knowledge Centre

86. There is an urgent need for the construction industry to develop a knowledge centre through which the whole industry and all of its clients can access to knowledge about good practices, innovations and the performance of companies and projects; in particular the knowledge gained from demonstration projects. It is important that the knowledge centre is objective, impartial and efficient. The DETR is already developing a Construction Best Practice Programme and we invite the Department to use this to create a national knowledge centre for construction.

Public Sector Clients

87. The public sector is the largest client of the construction industry. The Task Force recommends that the Government commits itself to leading public sector bodies towards becoming best practice clients. We believe that this process must begin with substantial improvements in the way that the public sector procures construction. In our view this can be achieved while still meeting the need for public accountability.

88. The Government has already demonstrated through Public-Private Partnerships and the PFI its ability to make radical and successful changes in its procurement policies. By defining precisely what is wanted from facilities and allowing the construction industry to respond in innovative ways, Government Departments and Agencies have begun to tap a rich seam of ingenuity which previously had been stifled by the traditional processes of prescriptive design and tendering. We wish to see this approach become the norm throughout the public sector.

Occasional Clients

89. This report is largely presented from the point of view of clients who are knowledgeable about the construction process. That is appropriate, since it is these clients who can give leadership to improvement in construction. We are conscious, however, that much new construction and repair and maintenance work is done for occasional and inexperienced clients, many of whom commission major projects. Such clients are often unfamiliar with the construction process and unable to provide the environment in which the industry can meet their needs efficiently. This is of great concern to the Task Force, since we wish to see significant performance improvements across the whole industry.

Branded Products

The Task Force believes that the construction industry must grasp the opportunity for improvement that is being offered by major clients, and take responsibility for delivering these improvements to all of its customers. The industry must create supply chains for one-off clients and a single-point of contact on projects. It must develop products and brands which exceed customers' expectations and give customers confidence in the reliability and integrity of industry.

90. The construction industry must also introduce independent and objective assessments of performance, comparable with the Which report or the JO Power survey, that can be used by its customers to understand the industry's products and choose between them. We recognise the scale of this challenge and that it will take many years to achieve. We see no other practical strategy that the industry can adopt to escape from the debilitating cycle of competitive tendering, conflict, low margins and dissatisfied clients.

91. We have included few specific recommendations in our report, though we have frequently suggested a way forward. This approach is deliberate; what the Task Force is looking for is a change of style, culture and process, not just a series of mechanistic activities. We look to clients, the industry and Government to put in place the necessary plan of detailed actions to deliver change. The Task Force's objective will have been achieved if the spirit of change becomes genuinely embedded in this deeply conservative industry. The members of the Task Force stand ready to help with the vital process of implementing change.

Summary

92. To summarise, the Task Force wishes to emphasise that we are not inviting UK construction to look at what it does already and do it better: we are asking the industry and Government to join with major clients to do it entirely differently. What we are proposing is a radical change in the way we build. We wish to see, within five years, the construction industry deliver its products to its customers in the same way as the best consumer-lead manufacturing and service industries. To achieve the dramatic increases in efficiency and quality that are both possible and necessary we must all rethink construction.

Department of Trade and Industry
1 Victoria Street
London
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Rethinking Construction: 2002

Achievements • Next steps • Getting involved

RETHINKING CONSTRUCTION

clients, industry and government working together to improve UK construction

Our vision

is for the whole UK construction industry to create self-sustaining continous improvement leading to world class performance and better profitability

Rethinking Construction: 2002

A to Z
OF PARTICIPATING ORGANISATIONS

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OF PARTICIPATING ORGANISATIONS

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ABB Steward
Abbey Civil Engineering
Abbey Holford Rowe Architects
Acanthus, Lawrence & Wrightson
Accord
Accord Jarvis
ACIS Group
ACL Structures
ACO Technologies
Acoustic Design Technology
Actaris
Acton Housing Association
Adams Kara Taylor
Ainsworth Spark Associates
Airedale Glass and Glazing
Airways Housing Society
Aldwyck Housing Association
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Anchor Trust
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Architectural Association
Architon Group Practice
Arena Housing Association
Argent Development Consortium
Argent Estates
Artex-Blue Hawk
Arup
Arup Acoustics
ASH Consulting Group
Association of Consultant Architects

Introduction from the chair

It is quite incredible to see how much progress we have already made in implementing the recommendations for radical change set out in Sir John Egan's "Rethinking Construction" report. The scale and results of our current work programmes are truly impressive.

At the core of this programme are some 400 Demonstration Projects valued at £5.6bn, involving sustained participation by more than a thousand individuals representing client and supply side organisations of all sizes. Innovations and best practices are regularly being shared through our 10 Regional Cluster Groups. In some clusters Rethinking Construction Centres are now evolving to bring together networks of local organisations and interest groups that are also working in support of the Rethinking Construction agenda.

At a practical level we have provided the tools to support performance measurement, benchmarking and targeted continuous improvement, and focused industry attention on the critical areas of sustainability and Respect for People. We have regularly published the Key Performance Indicator results that have consistently made the business case for applying Rethinking Construction in practice, and organised some of the best supported conferences and events on significant developments such as off-site manufacturing, the housing sector and knowledge management.

We would not be succeeding without the tremendous support and commitment from our sponsoring Departments, the Housing Corporation, the Members of our Boards of Management, working groups and industry supporters, and the efforts of our implementation Team. But most of all our success comes from the work of the people and companies on the Demonstation Projects.

Our Industry is vast and fragmented. We have made excellent progress to embed the lessons of Rethinking Construction but I am acutely aware that there is so much more to do. This brochure explains what we are already doing and most importantly explains how you too can get involved. I urge you all to consider – for good business reasons – the ways in which you can get involved.

Alan Crane

Chair, Rethinking Construction Ltd.

2002 – a milestone

This snapshot of Rethinking Construction in 2002 tells you:

– *What we have achieved,*

– *What we are doing over the next two years, and*

– *How you and your organisation can join the challenge.*

What is Rethinking Construction?

Rethinking Construction was initiated by the report of the Construction Task Force chaired by Sir John Egan in 1998.

The principles are simple:

– *Client leadership,*

– *Integrated teams throughout the delivery chain, and*

– *Respect for people.*

The objectives are to achieve radical improvements in the design, quality, customer satisfaction and sustainability of UK construction and to be able to recruit and retain a skilled workforce at all levels by improving its employment practices and health and safety performance.

The task force proposed seven targets for improvement, which underpin Rethinking Construction:

– *Reduced capital cost*

– *Reduced construction time*

– *Better predictability*

– *Fewer defects*

– *Fewer accidents*

– *Increased productivity*

– *Increased turnover and profit.*

How are we doing it?

Since the publication of the report, the Rethinking Construction agenda has been taken forward through a dynamic partnership between government, clients and industry. This has been given a further boost by the creation in 2001 of the Strategic Forum for Construction that brings together all the key industry representatives in pursuit of improvement.

At the heart of the Rethinking Construction initiative is the Demonstration Projects Programme. This provides the opportunity for leading edge organisations to promote projects that demonstrate innovation and change which can be measured and evaluated. These are either site-based projects or organisational change projects.

To date there are more than 400 of these projects in the programme, which taken together outperform the average of the UK industry against the key indicators.

A to Z OF PARTICIPATING ORGANISATIONS

Association of Consultant Engineers
Autronica
Avebury International
Avillon
Axa Power
AYH Partnership

b

B.E.E.
BAA
BAA/AMEC (The Pavement Team)
Babcock Water Eng.
Babtie Group
Bachy Solentache
BAe Systems
Bailey Partnership
Balfour Beatty Construction
Balfour Beatty Major Projects
Balfour Kilpatrick
Balfour Maunsell
Ballast Wiltshier
Barber, Casanouas and Ruffles
Barclays Bank
Bardon Contracting
Barnes Construction
Barnsley Metropolitan Borough Council
Barrie Tankel Project Management
Bartram's Elec
Barwick Construction
Bathsystem SA
Battle McCarthy
Beacon Housing Association
Beale & Cole
Beaver Housing Society
Beazer Group
Bechtel Morrison JV
Bechtel Water Technology
Bedfordshire Pilgrims Housing Association
Bellway
Benfield Construction
Benard Ede/A. Grant Associates
Bennetts Associates
Benson
Bentalls
Berkeley Festival Waterfront
Bertram Sheppard
Best Practice Club
Bevan Ashford Solicitors
BG Transco
Bickerdike Allan Partners
Bidwells
Bielski Associates
Billingham Campus
Billington Structures
Bingham Cotterell
Binnie Black and Veatch
Birchdale Glass

A to Z
OF PARTICIPATING ORGANISATIONS

Birmingham City Council
Birse Construction
Birse Plant Hire
Bison Concrete Products
Bison Structures
BIW Technologies
Biwater Industries
Biwater Treatment
Black Country Housing & Community Services Group
Blackfriars Investments
Blackpool Borough Council
Blackwall Products
Blair Rains
Bleak Hill School
Blyth & Blyth
BNFL Engineering
Boothe King Partnership
Boots The Chemist
Bovis Lend Lease
Boxall Sayer
BP Chemicals
BP Oil
Brain Warwicker Partnership
Braintree District Council
BRC
BRE
Brian Canavan Assoc.
Bridon International
Brighton & Hove City Council
Bristol City Council
British Aerospace Systems
British Cement Association
British Gypsum
British Nuclear Fuels
British Waterways
Britspace
Britspace Yorkon Joint Venture
Broadland Housing Association
Bromford Carinthia Housing Association
Broomleigh Housing Association
Bruce Oliver
Brunswick Millennium
BSRIA
BT
Buckinghamshire County Council
Bucknall Austin
BuildEurope Group
Build on line
Building Design Partnership
Building Information Warehouse
Building Management
Building Research Establishment
Building Services
Bullen Consultants
Burnley Wilson Fish
Buro Four Project Services
Buro Happold

Because of the progress we are making, the Department of Trade and Industry gave the Rethinking Construction initiative continuing financial support for a further two years from April 2002. It is also backed through the direct engagement of hundreds of companies and industry organisations, government departments including the Treasury and the Department of Transport, Local Government and the Regions, as well as the Housing Corporation.

Each day, more and more organisations are getting involved with Rethinking Construction as the impact of our work gathers momentum.

Enlightened clients are seeking to work with people who are committed practitioners of this agenda. At the same time the government is requiring the principles of Rethinking Construction to guide clients' procurement practices in both central and local government.

Our four key strategic objectives

1. ***Proving and selling the business case for change*** – Through effective monitoring and evaluation of Demonstration Projects and Organisations, and the collection of KPIs, to deliver clear evidence to the industry that continuous business improvement is achieved by following the principles and targets of Rethinking Construction. To place particular emphasis on clients, integrated supply teams and respect for people issues.
2. ***Engage clients in driving change*** – To encourage clients to promote Rethinking Construction though involvement in demonstrations and commitment to the Clients' Charter.
3. ***Involve all aspects of the industry*** – To ensure that every sector of the industry is represented by active demonstration of the Rethinking Construction principles.
4. ***Create a self-sustaining framework for change*** – To ensure that the industry takes responsibility for developing and maintaining continuous improvement, nationally and regionally.

All this is underpinned by the programme of dissemination, support and advice provided by the Construction Best Practice Programme.

What is left to be done?

The key areas still to be addressed by Rethinking Construction are:

- *Continue to prove the business case through demonstrations, with a growing emphasis on organisation change projects.*
- *Identify gaps in the business case that need to be filled.*
- *Identify gaps in industry involvement, taking the message to SMEs and encouraging their wider engagement.*
- *Build a strong national support network across all the English regions, Northern Ireland, Scotland and Wales.*

How can you get involved?

Would you like to work with us or find out more? We would very much welcome your involvement.

You can do this by:

- *Nominating a Demonstation Project*
- *Becoming a member or sponsor*
- *Joining a working group that would benefit from your expertise*
- *Supporting your local Construction Best Practice Club*
- *Participating in Rethinking Construction events that are run across the UK.*

Because of the varied nature of the industry and its products, there are a number of streams of activity within the Rethinking Construction initiative. These are:

The Movement for Innovation (M^4I) – which focuses on the general construction industry,

The Housing Forum – which concentrates on the public and private housing sector,

The Local Government Task Force – which is promoting the Rethinking Construction agenda within local authorities as major clients,

The Respect for People Steering Group – which is currently trialling a series of toolkits to help improve recruitment, retention and health and safety, and

The Construction Best Practice Programme – which is the main dissemination arm for Rethinking Construction.

We are also building an extensive support network in the regions, as well as in Wales, Scotland and Northern Ireland.

Contact details for all these groups are shown on page 19.

A to Z OF PARTICIPATING ORGANISATIONS

Bute Housing Association
Byrne Brothers

C

C. McDonnell
C.H. Construction
CA Blackwell
CA Cornish
Cadarn Housing Group
Cala-Morrison
Caldmore Area Housing Association
Caledonian Water
Callcott Anderson Design Consultants
Camargue
Campbell Reith Hill
Cambridge City Council
Cambridge Van Leyden
Cambridgeshire County Council
Camelot Distribution
Cameron Taylor Bedford
Camtwix Engineering
CAP Aluminium
Cappagh Public Works
Capper Pipe Services
Cardon Gent
CARES
Carillion Building
Carillion Construction
Carillion Housing
Carillion Infrastructure & International
Carlisle City Council
Carr-Gomm Society
Carter Refrigeration
Castle Vale Housing Action Trust
Catalyst
Catchment
Cavill Fabrications
CCR
CEGELEC
Cegelec Projects
Central & Cecil Housing Trust
Centre for Alternative Technology
CES
Chandler KBS
Chapman Taylor Partners Architects
Charlton Triangle Homes
Chartered Institute of Building
Charterhouse
Cheserfield BC
Cheshire County Council
Chesterfield Borough Council
Chesterton International
Chetwood Associates
Chiltern Hundreds Housing Association
Chris Blandford Associates
Christchurch Borough Council
Christchurch Junior School
Christopher Smith Associates

A to Z
OF PARTICIPATING ORGANISATIONS

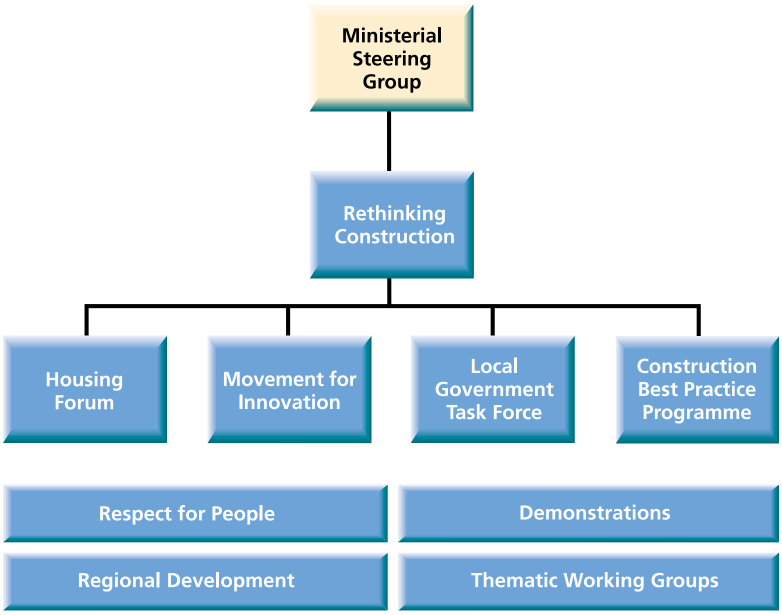
CIMCO
Circle 33 Housing Trust
CIRIA
CIRUS
CIT
CITB
CITEX
City and County of Swansea
City Engineering Services
City of Bradford Drainage Design Department
City of Stoke-on-trent
Civil & Industrial Products
Cladspec
Clarke Bond Partnership
Client Architect
CMC
Coastline Windows
Cochrane McGregor
Colledge Trundle & Hall
Collingwood Housing Association
Collis Heating
Commercial Management Consultants
Community Housing Association
Community Self-Build Scotland
Comsite Projects
Concepts Architects
CONNECT 2020
Consafe
Consarc Design Architects
Conspec Contractors
CONSTRUCT
Construction for Business
Contano
Cook & Butler partnership
Coral Construction
Cornwall County Council
Corus
Corus Construction Centre
Costain
Costain Civil Engineering
Countryside in Partnership
Countryside Strategic Projects
Coventry City Council
Crabtree
Craig White Design
Crerar & Partners
Crest Nicholson Properties
Crossbrook Furniture
Crown House Engineering
Cruden Homes (Scotland)
CSA Consulting Engineers
CTSG
Cundall Johnston & Partners
Currie and Brown
Curtins Consulting Engineers
CV Buchan
CWS Engineering
Cyril Sweett & Partners

Working together

Following a decision to streamline the Rethinking Construction initiative, so that all the related parts work together under this brand, progress is now being made towards completing this process.

A single company, Rethinking Construction Ltd, acts as the main point of co-ordination and liaison between the various streams. The chairs of the Housing Forum, M^{4}I, the Local Government Construction Task Force and the director of the Construction Best Practice Programme serve on the Board. The DTI attend as observers.

The company also acts as the main vehicle for the executive support of the initiative, and receiver of sponsorship, subscriptions and funding. The Construction Best Practice Programme is funded through a separate DTI contract with BRE.



Movement for Innovation *www.m4i.org.uk*

RETHINKING CONSTRUCTION Movement for Innovation M^{4}I

The Movement for Innovation (M^{4}I) takes the lead in promoting Rethinking Construction among the *non-housing* sectors of the UK Construction Industry and related trade and professional organisations. The Board of Management is responsible for the performance and learning outputs from the M^{4}I Demonstration Projects, and has led the development of the Key Performance Indicators and the Environmental Performance Indicators. The Movement is partly financed by Supporters and Members as well as the DTI.

M^{4}I is developing the regional network for Rethinking Construction, through its Demonstration Projects cluster programme. These clusters are now expanding to embrace the Housing Forum Demonstration Projects.

M^{4}I is promoting Rethinking Construction badged events, following the success of its *Off-site Fabrication* conference last year, and a *Knowledge Management* event in April 2002. It is also jointly supporting a series of seminars on *Lean Construction*.

The M^{4}I Board members are listed on page 16.

Housing Forum www.thehousingforum.org.uk

The Housing Forum was set up to bring together everyone in the house building chain in a movement for change and innovation in dealing with new construction and renovation of the existing stock. The Housing Forum embraces leading edge suppliers, house builders, social landlords, local authorities, designers, contractors, consultants, housing trade bodies and professional institutions, who are seeking continuous improvement in quality, efficiency, sustainability and value for money.

The Housing Forum set up the National Customer Satisfaction Survey that will become the regular measure of progress for speculative house builders, and established a Benchmarking Club for its members to develop housing sector specific key performance indicators. It has developed Housing Sector Key Performance Indicators for refurbishment, repair and maintenance works, and it has published reports on key themes.

The Forum is partly financed by Core and Open Members, and by the Housing Corporation and the DTI.

Housing Forum Board members are listed on page 17.

Local Government Task Force www.lgtf.org.uk

The LGTF was established in March 2000 to encourage and assist local authorities to adopt the principles of Rethinking Construction. As one of the biggest spending clients in the country on construction, maintenance and repair works, it is vital that councils achieve the improvements and savings that Rethinking Construction can bring. By focusing on the whole-life costs of a project, rather than cheapest initial tender costs, local authorities can ensure that they meet their Best Value obligations, and deliver high quality services to the people they serve. The LGTF publishes advice and guidance to local authority practitioners, designed to maximise their efficiency and effectiveness. By avoiding waste, duplication and dispute, they ensure that they are best serving the needs of their community; giving them more for less.

Working closely with the Movement for Innovation and the Housing Forum, the LGTF focuses attention on their Demonstration Projects, and the very real improvements that these bring to the construction process.

The LGTF has close links with other organisations that represent local authorities, such as the Local Government Association, Improvement and Development Agency (IdeA), Chartered Institute of Public Finance Accountants (CIPFA), and the Department of Transport, Local Government and the Regions (DTLR).

LGTF Board members are listed on page 18.

Respect for People www.rethinkingconstruction.org.uk

Respect for People (RfP) is fundamental to achieving world class performance in construction. It is a crosscutting theme throughout the strands of Rethinking Construction. Following the launch of the report *A Commitment to People "Our Biggest Asset"* by the then Construction Minister Nick Raynsford in November 2000, there has been extensive trialling of a series of toolkits and Key Performance Indicators.

d

D Campbell & Company
D H Morris Group
D&R Scaffold (London)
Dave Dickinson & Associates
David Cartwright
David Crewe Associates
David Stroud Associates
David Wilson Homes
Davis Langdon Consultancy
Davis, Langdon & Everest
DCT Civil Engineering
Deakin Walton Consulting Engineers
Deane & Amos Shopfitting
Dearle & Henderson Consulting
Defence Estates
Delva Patman
Dene Mechanical
Denis Wilson Partnership
Denley King Partnership
Denne Group
Dennis Lister & Assoc
Derwent Housing Association
Design Council
Design Selectric
DesignHaus
Deva
Devon & Cornwall Housing Association
Devon Community Housing Society
Devon County Council
Devonport Management
Diocese of Portsmouth
Dixon Contractors
Dixon Jones Architects
Donal Hayes & Sons
Donald Smith, Seymour & Rooley
Doncaster Borough Council
Dorset County Council
Dorset Engineering Consultancy (DEC)
Downey & Warren
Dr. Amato
Dudley Metropolitan Borough Council
Dula UK
Dundee City Council
Dundee Plant Company
Durham County Council
Durkan
DVS
DWr CYMRU/Welsh Water

e

E Poole
E Thomas Construction
E.C. Harris
Ealing Family Housing Association
Earth Tech/Farrans (JV)
East Dorset Housing Association
East Midlands Housing Association
East Riding of Yorkshire County Council

A to Z OF PARTICIPATING ORGANISATIONS

East Sussex County Council
East Thames Housing Group
ECS
Eden Housing Association
Edmond Shipway
Edmont Joinery
Education Workshop Services
Edward Cullinan Architects
Edward Roscoe Assoc.
Edwards Project Management
EH Smith
EI WHS
EIC Contract Services
EIC South West
Eidetic
Eildon Housing Association
EJ Badekabiner
Elgar Housing Association
Ellesmere Port & Neston Borough Council
Emcor Drake & Skull
Engineering Construction Industry Association
Engineering Solutions
English Architectural Glazing
English Churches Housing Group
English Partnerships
Enviromental Services, Oxfordshire County Council
Environment Agency
Environment Agency Wales
Envirowise
EPR Design
EPS Maintenance
EPSRC
Equity Bank
Essex County Council
Essex Electrical
ESU Services
Europump Services
Evesham and Pershore Housing Association
Eveson Environmental
ExCal
EXOR Corporation
Express Reinforcements
Exterior Construction Management

f

F B Gilmers
F W Cook
F W Marsh Electrical
Fairclough Homes
Fairhursts
Faithful & Gould
Family Housing Association
Family Housing Association (Wales)
Farrans (Construction)
Faucets

The work now involves over 100 companies across the UK representing every sector of the industry, and covers seven themes:

- *Diversity in the workplace,*
- *On-site working environment,*
- *Health,*
- *Safety,*
- *Working conditions off-site,*
- *Career development & lifelong learning, and*
- *Behaviour.*

The first ever set of industry Respect for People KPIs have been produced and were launched in May 2002. They are available from the Construction Best Practice Programme.

RfP toolkits are available from Rethinking Construction. Aimed at line management they are unique within the construction environment and can be used to underpin progress towards the Investors in People standard or European Foundation for Quality Management Business Excellence approaches. The revised set – developed in response to the trialling – will be published in the autumn.

The Respect for People Steering Group is listed on page 17.

Construction Best Practice Programme

www.cbpp.org.uk

The Construction Best Practice Programme (CBPP) is an integral part of the Rethinking Construction initiative. A recent survey showed that more than 90% of users acknowledged that the programme has brought financial benefits to their company.

The main drive has been to improve the business management of construction through the delivery of services to the sector and the dissemination of best practice information. The CBPP plays a specific role in continuous business improvement, providing opportunities for individuals, business teams, entire companies and supply teams to engage in best practice. More than this, the CBPP is about raising awareness, gaining commitment and facilitating the sharing of knowledge.

Its 1500 publications include case studies, profiles, guides, and more than 150 director's briefings and information on the learning by doing workshops. Users will benefit from the recent establishment of a team of 40 best practice advisers.

More than 250,000 user sessions recorded on the CBPP Website show that the industry has adopted the Programme as a key method for learning.

CBPP also aims to support companies in the construction sector make better use of information technology. IT Construction Best Practice brings together expertise and guidance on the effective use of IT throughout the construction industry. Companies that register with ITCBP receive guidance material, much of it free of charge, including case studies, guides, reports and other material, as well as updates on events and industry news. *www.itcbp.org.uk*

The Programme is funded by the DTI.

Contacts for the Construction Best Practice Programme are shown on pages 19 and 20.

Across the UK

The day to day management of the Movement for Innovation and the Housing Forum Demonstration Projects is conducted locally through the Regional Clusters. Regional Co-ordinators (listed on page 19) develop the Regional Clusters and facilitate the demonstrations.

The Clusters reflect the boundaries of the Regional Development Agencies and the devolved Government in Scotland, Northern Ireland and Wales. More precise alignment with the RDA boundaries will be introduced by the end of the year. Each Demonstration Project has been allocated to one of the Regional Clusters – normally based on the construction site location.

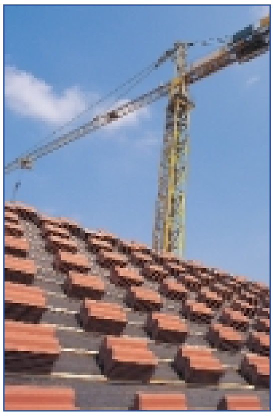
How the Clusters work

Each Regional Cluster is managed by its own management group, recruited from the representatives of the Demonstration Projects and other leading local enthusiasts. Senior industry representatives from the Movement for Innovation and the Housing Forum support them.

A Cluster, evolved from the M^4I startup, is a forum for those committed to Rethinking Construction to meet regularly and to exchange ideas in a non-commercial, cross industry environment. They encourage local debate about the detail of project innovations and best practices. They promote the practical outputs of the Rethinking Construction Programme to a wide spread of regional and local interest groups including clients, suppliers, industry organisations, universities and others. The central Rethinking Construction organisation relies on the Clusters for feedback on regional and local issues and needs.

The Clusters are establishing links with regional business, industry and client organisations that share the Rethinking Construction agenda, or have a vested interest in the value for money and quality of the industry's output. The Clusters are engaging with the Regional Development Agencies, key Local Authorities, regional groups of trade and professional organisations, and local Construction Best Practice Clubs (see page 20).

Towards a National Network



Our strategy includes an integrated, UK wide network of mutually supportive organisations working to maintain the energy and enthusiasm for Rethinking Construction in the long term.

Two meetings of Rethinking Construction organisations in the regions have taken place; the first at Manchester in December last year and the second at Cardiff in March, each with more than 50 delegates taking part. These meetings confirm the tremendous support for a National Network of regional organisations that will facilitate a wider take up of Rethinking Construction, and disseminate its benefits further.

In Northern Ireland and Wales local networking has developed to such an extent that formal Regional Rethinking Construction Centres have been established. These Centres bring together the key local representative interests working in support of Rethinking Construction, under a single management structure. In Northern Ireland the local Board of Management has overall responsibility for the operation of the Regional Cluster. It is hoped that similar structures will emerge in other regions.

Lesley Chalmers is your contact for more information on our National Network. Tel: 0207 256 2100, or Email: Lesley.chalmers@btinternet.com.

A to Z
OF PARTICIPATING ORGANISATIONS

Faulkner Brown
fch Housing & Care
Feilden Clegg Architects
Fenwick Elliot
Ferguson McIlveen
Fernwave
FES Water Technology
Fibbens Fox Associates
Fife Belcher Grimsey and Partners
Fillcrete
FISEC
Fitch
Fitzpatrick
Flagship Housing Group
Floorscape Contracts
Flowline Civil Engineering
Flynn Willoughby
FM Modern Design
Focus Housing Group
Foggo Associates
Forge-Llewellyn Co
Forticrete
Fosseway Housing Association
Foster & Partners
Frank Haslam Milan
Franklin & Andrews
Fulcrum Consulting

g

G H Marshall
G Rolph & Sons
G&S Roofing
Gaffney, Cline & Associates Retirement Fund
Gallaher
Galliford
Gallions Housing Association
Galmalco
Gardiner & Theobald
Gary A Powell & Associates
Gateshead MBC
Gavin Jones Landscape
Gazeley Properties
GBM Build
gcp Chartered Architects
Gensler Int.
Geoffrey Osborne
Geoffrey Reid Associates
George & Harding Construction
George Trew Dunn
Gerald Tobias Associates
Getjar
Gibb
Gifford & Partners
Gilbert and Stamper
Glamox Electric
Glamox International
Glass Block Design & Build
GlaxoSmithKline

A to Z
OF PARTICIPATING ORGANISATIONS

Gleeds Management Services
Gleeson City Living
Gleeson Homes
Glencroft Civil Engineering (Manchester)
Gloucestershire County Council
Gloucestershire Housing Association
GMW Partnership
Gold Consulting
Goodson Associates
Gordon Durham & Co
Gordon Harris Partnership
Gosport Borough Council
Graham Mather Associates
Graham Wood
Grangefield School
Grant Westfield
Granta Housing Society
Granville Steel
Green Family Homes
Green Globe 21
Greenwich Healthcare Trust
Grendon Building Services
Grosvenor Housing Association
Grundfos Pumps
GTMS Scotland
Guardian Properties
Gusto Construction

h

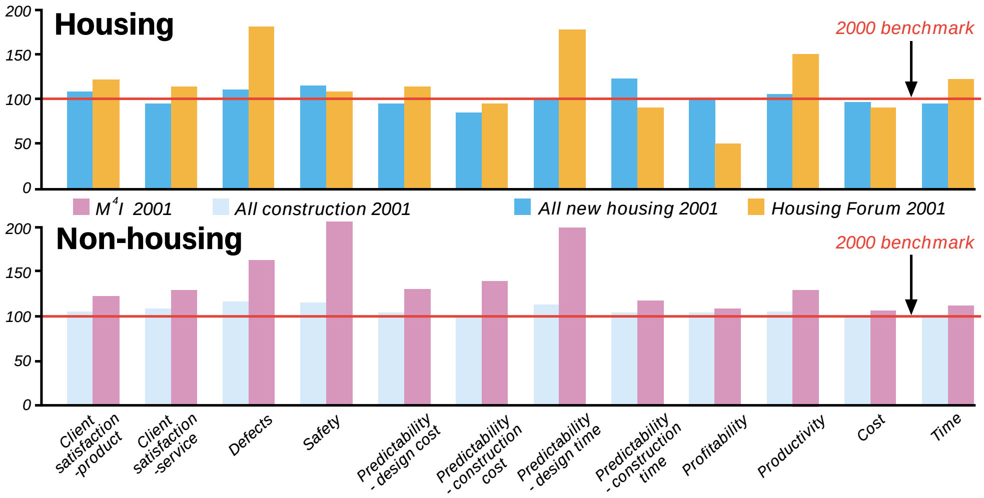
H & H Celcon
H&H Celcon
H&J Martin
Habinteg Housing Association
HACAS Asset
Hackney Building Maintenance
Haden Young
Hadfield Cokwll & Davidson
Halcrow Management Sciences
Halcrow UK
Halcrow Waterman
Halifax
Hall & Kay Fire Engineering
Hammerson UK Properties
Hampshire County Council
Hancock Ward
Hanover Housing Association
Hanson Aggregates
Hanson Concrete Products
Harbour and General Works
Harper Mackay
Hart Builders (Edinburgh)
Hart Housing Association
Hartley & Kovats
Harvest Housing Group
Harvey & Co
Hastoe Housing Association
Hathaway Roofing
Havelock Housing Association
HBG (Netherlands)

Good for business

This year we have measured the performance of 99 M⁴I and 53 Housing Forum Demonstration Projects. Team members collected the data and worked with the projects to ensure consistent interpretation and application of the KPI measures. The graph below compares the Demonstration Projects with relevant industry sectors in 2001.

Housing Forum Demonstration Projects have again out performed the industry averages for most of the KPIs, in their second year of monitoring. The Housing Forum shows particular strength in reduced defects, predictability and productivity.

M^4I Demonstration Projects have also out performed the industry averages for all the KPIs, in their third year of monitoring. M^4I is particularly strong in reduced defects, predictability and safety.



The big picture results provide an irrefutable business case for Rethinking Construction

Clients are happier – On average Demonstration Projects are showing an 11% increase of client satisfaction over the industry.

Quality is increasing – An average of 30% more projects are reporting few or no defects.

It's a safer place to work – Demonstration Projects are consistently shown to be safer sites. Current figures show them to be 25% safer than the industry at large.

Keeping promises – 15% more Demonstration Projects are finishing on or ahead of programme and budget than in the rest of the industry.

More Productive Workforce – Our Projects are showing that the average value added per employee is £10,000 more than the industry figure.

Quicker Projects – the Demonstration Project process is showing that on average they are completing schemes 10% quicker than 1 year ago.

How have we done it?

The Demonstration Projects are achieving these results by performance measurement and benchmarking, long term partnering, integrating supply chains, sharing risks and rewards, establishing the culture and providing incentives for the elimination of waste in all its forms, and improving working conditions for employees. That's Rethinking Construction!

Housing Forum 2001 | All new housing 2001 | M[4]I 2001 | All construction 2001

KPI	Measure	Housing: Housing Forum 2001	Housing: All new housing 2001	Other Construction (M[4]I): M[4]I 2001	Other Construction (M[4]I): All construction 2001
Client satisfaction – product	% scoring 8/10 or better	80%	69%	85%	73%
Client satisfaction – service	% scoring 8/10 or better	67%	58%	80%	65%
Defects	% scoring 8/10 or better	91%	53%	86%	58%
Safety	Mean accident incidence rate per 100k empl.	1003	993	495	990
Predictability – design cost	% on target or better	67%	60%	81%	63%
Predictability – construction cost	% on target or better	54%	46%	71%	50%
Predictability – design time	% on target or better	72%	41%	81%	46%
Predictability – construction time	% on target or better	48%	62%	70%	61%
Profitability	Median profit before interest and tax	3%	6%	5.8%	5.6%
Productivity	Mean turnover / employee	£42k	£28k	£34k	£28k
Construction cost	Change compared with one year ago	+8%	+3%	-2%	+2%
Construction time	Change compared with one year ago	-12%	+11%	-8%	+4%

Notes on KPIs where Housing Forum projects underperformed against industry averages:

Safety – Of the projects reporting on safety, the two reportable accidents (neither serious) had a disproportionate effect on this statistic.

Predictability of construction time and profitability – A number of projects reported difficulty with supply of timber frame components, impacting noticeably on construction time and profitability scores.

Cost – Many housing projects are trialling energy and resource conservation measures and have included the cost of research and development. Some projects are also reporting high initial costs of partnering initiatives.

A to Z
OF PARTICIPATING ORGANISATIONS

HBG Construction Southern
HBG GA Construction
Heathrow Airport
Hemsley Associates
Hepworth Building Products
Hertfordshire County Council
Hewden Crane Hire
Hexagon Housing Association
Heywood Williams
HG Construction
HGB Construction
HGB Design
HGP Architects
Higgins Group
Hightown Praetorian Housing Association
Highway Surfacing
Highways Agency
Hiilti (GB)
Hill Partnerships
Hills Electrical
Hinkins & Frewin
Hoare Lea & Partners
Hochtief/Griffiths jv
Holden & Lee
Home Housing Group
Honeywell Control Systems
Horizon Housing Group
Hotchkiss Ductwork
Hotels & Catering Intl. Assoc.
Howdens Joinery
HQ Executive Offices (UK)
Hull City Council
Hurley Palmer Flatt
Hurley Palmer Partnership
Hurley Robertson Associates
Hutter, Jennings & Titchmarsh
HY Arnold
Hyde Housing Association
Hyder Consulting
Hydrax
Hy-ten Reinforcement Co

I

I & J Munn
Icon Structures
Impact Housing Association
Imperial College of Science, Technology & Medicine
Industrial Dwellings Society
Integra (Brighton)
Interior
Interserve
Interstat (UK)
Institution of Civil Engineers
IPM
Irwell Valley Housing Association
Isherwood & Boyd
Isis Accord

A to Z
OF PARTICIPATING ORGANISATIONS

Isle of Wight Housing Association
Islington County Council
ITT Direct

J

J Sainsbury
J U Bowen (Construction)
Jackson Building
Jackson Civil Engineering
Jackson Coles Partnership
James Burrell Builders Merchants
James Butcher Housing Association
James Killelea & Co
James Scott
Jarvis
Jarvis Construction (UK)
Jeld Wen (UK)
Jestico & Whiles
Jewson
JMP Consultants
John Carlisle Partnerships
John Doyle Construction
John Gibbs Partnership
John Grooms Housing Association
John Laing
John Martin Construction
John Mowlem Construction
John Youngs
Jones Environmental (Ireland)
Joywheels
JPS Environmental Services
Jubb & Partners
JWA Architects

k

K&N Welding
Karl Blacton
Kelly Taylor & Associates
Kelsey Housing Association
Kelsey Roofing Industries
Kendall Kingscott Partnership
Kensington Housing Trust
Kent County Constabulary
Kent County Council
Kent Police Authority
Kent Structural and Marine
Kerr Duncan McAllister
Kestner DJM Pollution Control
Kestral Tech Services
Kier Build
Kier Construction
King Alfred's College of Higher Education
Kingsbridge Community College
Kingston Hospital NHS Trust
Kingston upon Hull City Council
Kirk McClure Morton
Knauf UK
Kone Lifts

The 12 KPIs demonstrated

CLIENT SATISFACTION – PRODUCT

Bryce Road Phase 2A, Dudley – Housing Forum

The race is on to design houses that demand fewer non-renewable resources. The Green Futures team is monitoring and comparing emerging green technologies and consulting residents to see how realistic it is to adopt the more promising ideas. Finding consultants, contractors and suppliers ready to develop and trial new solutions is half the battle. Making it work within Housing Corporation budgets is the other.

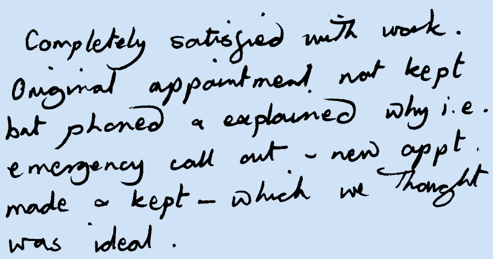
The Black Country Housing and Community Services Group, awarded the 'product' top marks for packaging innovations – such as solar heating, insulation, airtight construction, managed ventilation, and sun tubes – that promote sustainable, modern living. Combined heat and power, ground source heat pumping, water and waste management systems are on trial.

CLIENT SATISFACTION – SERVICE

Measured term contracts, Northern Ireland – M4I

Construction Service Northern Ireland manages maintenance and minor works for numerous government departments and agencies, under measured term contracts. Measuring the scope of work for payment is relatively straight forward, but measuring customer satisfaction was almost impossible because of the large number of orders and the remoteness from end users. Then they were introduced to Referenceline, another M4I Demonstration Project.

Customers are asked to complete a simple score card on the value, quality, service and response. Referenceline analyses the data and prepares a monthly customer satisfaction report on each contract. Customer satisfaction scores are impressive overall and the feedback is a practical tool for working with contractors who need to improve their service.

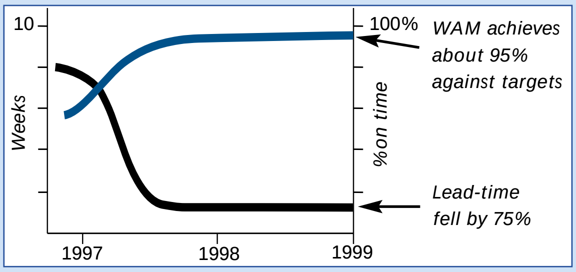


CONSTRUCTION TIME

Waterloo Air Management, Maidstone – M4I

In the mid 90s, Waterloo Air Management (WAM) had a serious financial problem. Like so many other construction supply businesses, they were always running hard just to stand still. The Rethinking Construction report convinced the board that partnering provided the answer to the most difficult business question of all – how to become truly customer focused.

A critical step in their transformation was to cut lead-time from typically 6-8 weeks to 1-2 weeks. This has a knock-on effect in the contractor's programme. Long-term partnering deals with key M&E contractors have led to WAM increasing market share in the core products from 15 to 25% over four years. WAM has broken its loss making habit and left years of red numbers behind.



CONSTRUCTION COST

North Tyneside schools programme – M4I

A continuing better value project by North Tyneside Council is proving itself with excellent results and savings, winning The Unexpected Special Award in Vision 100 – BT's selection of the UK's 100 most visionary companies. The challenge, arising from their Asset Management Strategy, is a four-year, £80m programme of renewal and refurbishment of schools.

Abandoning the traditional cost-driven, tender-led formula, they chose three main building contractors on quality criteria alone. These contractors formed a partnership with the council, creating 'a unique pool of experience'. The partners went on to solve the problem of how to get the best value from the supply chain, identifying five substantial work packages with high cost sensitivity – roofing, mechanical services, electrical services, floor finishes and external windows and doors.

By offering long-term work and harnessing the trade contractor's design expertise, North Tyneside is saving up to 50% on sensitive trade packages. They are well on the way to cutting the overall construction cost by 15% during the programme.

PREDICTABILITY – DESIGN COST

William Morris Court, Oxford – Housing Forum

The first steel-framed project by Oxford Citizens Housing Association has produced real programme improvements and reduced defects, while reinforcing the association's successful partnering approach with Oxford City Council and contractor Willmott Dixon. The primary partnership agreement was between Oxford City Council, Oxford Citizens and Willmott Dixon.

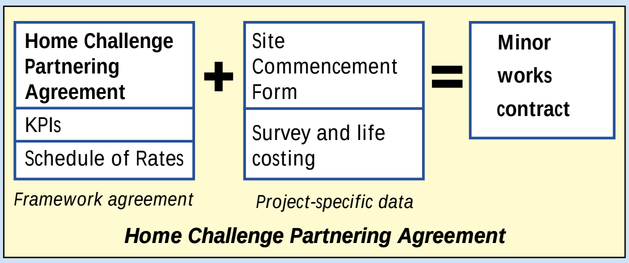
A wider, more informal partnership drew in other key players, including the designers MEPK. Each partner appointed a 'Tzar' to expedite the decision making process and ensure their unified commitment to the project. The results are some excellent KPI scores, including keeping the design cost well within budget, a performance within the top 10% of housing projects.

PREDICTABILITY – CONSTRUCTION COST

Home Challenge, South West – Housing Forum

Western Challenge Housing Association's new Home Challenge Partnering Agreement has proved a hit with contractors. Aimed at house refurbishment contracts, the agreement includes measured KPIs, ring-fenced overheads and profit and a shared savings formula not normally found in minor works.

The main criteria are completion to programme and budget. Historical figures showed that although the benchmark projects had cost (on average) about 5% less than budgeted, some 22% went over budget. The Demonstation Project performed much better. After the first year, Home Challenge was delivering 11% savings and only 4 out of 31 of projects had exceeded budget.



A to Z OF PARTICIPATING ORGANISATIONS

KPMG Management Consulting
KSB
Kwikform UK

LA Associates
L. B. Camden Housing Renewals
Lacey Hickie & Caley
Lafarge Plasterboard
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Lovell Construction
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Marley Building Materials (Thermalite)
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PREDICTABILITY – DESIGN TIME

Christ Church Court, London – M^4I

Christ Church Court was the first phase of the redevelopment of Paternoster Square adjacent to St Paul's Cathedral for developer Stanhope. John Doyle Construction was responsible for the complex substructure and associated groundworks, with construction manager Bovis Lend Lease.

There were a lot of small technical innovations, some in consultation with the British Cement Association, but the main reason the project succeeded was the proactive behaviour of the integrated project team.

It was a congested site demanding difficult, bespoke earthwork support and concrete installation. John Doyle Construction modelled the working procedure using a 3D graphics package run with Microsoft Excel. This enabled the project team to understand the process and procedure of the works and to execute them safely and without undue delay. The project's KPIs, including design time, were exemplary.

PREDICTABILITY – CONSTRUCTION TIME

Broomleigh HA Maintenance, Bromley – Housing Forum

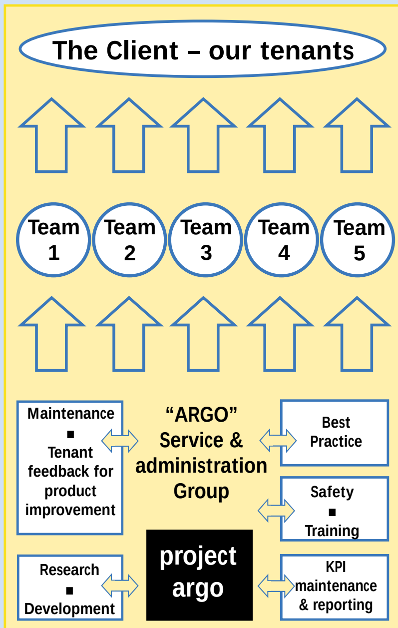
Repair and maintenance work has traditionally been done according to an agreed schedule of rates. The system promotes overspending because it encourages contractors to look for extras and discourages them from thinking about economy.

A partnering agreement with Geoffrey Osborne has saved Broomleigh Housing Association 10% of its total maintenance costs and boosted rental revenues. The partners have pushed the construction time predictability up by 10 points to 96%. Giving the contractor control of the work schedule has been a key reason for their success.

DEFECTS

Argo, Wear and Tees – Housing Forum

Project Argo is one of the early strategic partnerships of its type in the Housing Forum demonstration programme. There were initially six new-build schemes valued at £3m for 72 dwellings when the four-year initiative was launched in mid 1999. The team runs each scheme from initial feasibility, through Housing Corporation finance bidding, design, construction, and commissioning, all with open book accounting.



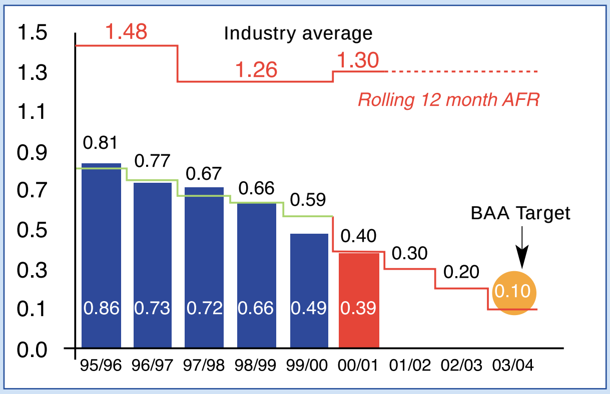
Home Housing Group managers are delighted with the success of their team – contractor Mansell, agent the NAP Partnership and designer P+HS Architects – in virtually eliminating defects. Argo schemes are rated 100% defects free, compared with nearly 60% of Home's non-Argo projects that suffer defects at handover.

SAFETY

One in a million – M^{4}I

In the public perception, there is probably no more safety aware industry than aviation. Before the Airport Construction Training Alliance (ACTA) existed, the accident frequency rate in BAA construction was half the average for UK construction. Yet it was some seven times worse than the petrochemical industry where there is evidence of an AFR below 0.1 reportable accidents per 100,000 hours (One in a Million). Matching this achievement looked like a mission impossible!

ACTA is a joint initiative between BAA and framework suppliers. The toolkit was developed specifically for airport construction, in consultation with the stakeholders – BAA, suppliers and construction workers. The focus is now on attitude and behaviour changes needed to reach their goal.



PROFITABILITY

Manufacturing: the business case for M&E – M^{4}I

BAA and MEPC, ever demanding yet enlightened clients, asked Crown House Engineering to do what is considered impossible by many in the construction industry today. They wanted better M&E services, faster and cheaper, over a five-year framework (BAA) and over six projects in Chineham Business Park (MEPC). Crown House delivered, AND they made more money in doing it!

Starting with their own manufacturing centre, sited adjacent to a supplier park, they already had a productivity advantage over more site-based operations. Their tactics include analysing value to reduce waste in the entire supply chain (this is never ending) and synchronising production with installation. Cross-functional teams are drawn from all members of the supply chain.

PRODUCTIVITY

Great Leighs Bypass, Essex – M^{4}I

Essex County Council is rising to the challenge of constructing highway schemes in a non-adversarial manner. Scheme finance was conditional upon a tight programme so traditional procurement was not the answer. The Council partnered with Alfred McAlpine under an NEC Option C Target Cost, design and build contract.

The team monitored their success by measuring National and site specific KPIs. The financial incentive was to share cost savings. Value Management reduced construction costs and the lean construction management team looked critically at how waste could be eliminated from the processes. Integrating the team of client, contractor and consultants boosted productivity by cutting duplication of roles.

A to Z
OF PARTICIPATING ORGANISATIONS

Morrison/Amec JV
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Optima Community Association
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P A Grant (Electrical)
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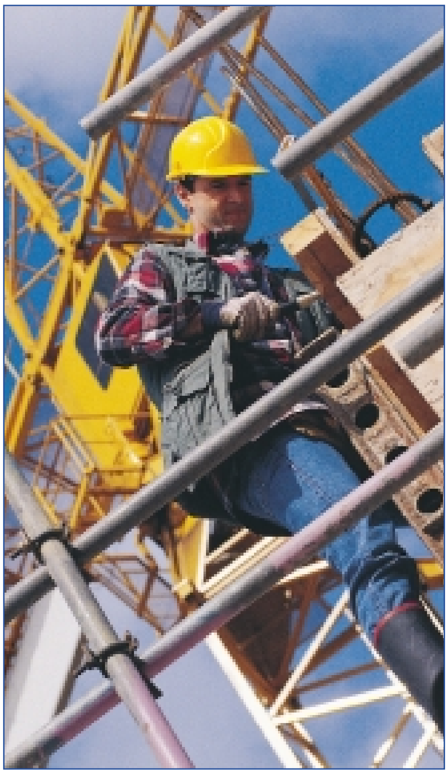
Panudda Foers

Who's who in Rethinking Construction?



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Bob White, chief executive of Mace, has taken over as chair from Alan Crane

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Graham Watts, chief executive, Construction Industry Council

Don Ward, chief executive, Design Build Foundation

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The Local Government Task Force

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Warrington Borough Council
Warwick Manufacturing Group

Construction Best Practice Clubs

CBPP has set up a national network of Construction Best Practice Clubs that meet on a regular basis to improve best practice in construction at a local level. The contacts for these clubs are listed below.

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Wates Construction
Watson Steel
WDR & RT Taggart
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Weeks Tech. Services
Welsh Development Agency
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Department of Trade and Industry

RETHINKING CONSTRUCTION INNOVATION AND RESEARCH

A Review of Government R&D Policies and Practices

By Sir John Fairclough

DTLR
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RETHINKING
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AND RESEARCH

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(i) FOREWORD

I wish to express my sincere thanks to the many people who have contributed to this Review. Their open and frank contributions have been of immense importance. I owe particular thanks to Liz Liston-Jones who has organised the Review and helped write the report. The conclusions are not of my own invention but have emerged from my discussions with industry and government representatives. My role has been one of a catalyst to understand how Research and Development (R&D) funded by Government might be better focused and lead to improvements in the overall construction process. I chose to take a broad view and I have considered design, planning, construction, and end use of buildings in an attempt to gain an insight into the role of innovation. I also examined the processes through which government R&D policies for the Construction Industry are determined and managed.

This Report was commissioned by, and is therefore primarily aimed at, the Government Departments responsible for sponsorship and regulation of the construction industry. There are important new challenges too for the industry, the research community, and its clients – not least for the rest of Government in its role as the major client of the industry. I hope they will all take time to digest and discuss the recommendations in this Report, as I believe all have much to gain from joining forces to act upon its recommendations.

Everyone in the country stands to benefit from a modern, efficient, high quality and good value construction industry. Innovation, driven by well founded R&D, is the best way forward.

(ii) EXECUTIVE SUMMARY

The innovative capacity of an industry influences its long-term competitiveness and effectiveness. R&D is an important driver of innovation. No valid argument was presented to justify the construction industry being any different – R&D is as important to the construction industry as any other. But it is not given the same priority as measured in R&D expenditure as a proportion of turnover. The construction industry organises its resources around projects and although it is evident that considerable innovation occurs and is funded within projects there is a problem with institutional learning to capture this innovation for future projects.

It is universally recognised that the industry must improve its performance. There are many pressures not least of which is the need for the industry to become more profitable and at the same time, deliver better value for money. The Strategic Forum, which reflects the interests of the whole industry, has recently been established, and is concentrating its initial energy on some key issues of fundamental importance to delivery of the vision set out in Sir John Egan's report 'Rethinking Construction'. This represents a bold initiative to break the mould of outdated and often adversarial processes that operate in the sector. Sir John Egan did not consider the role of R&D in his report, but having made considerable progress in getting the industry to focus on the need for change it is now timely to do so. Sir John acknowledges that a carefully focused R&D programme will be required to support the work of the Strategic Forum.

Once the immediate activities of the Strategic Forum have been initiated, they will have an opportunity to build an outward looking vision. The sector has suffered from a lack of focus and an ability to speak with a single voice on those issues that influence it and its stakeholders as a whole. The sector needs a vision – a strategic perspective – not least because effective R&D must be driven from clear strategic goals.

The sector has a profound influence over our quality of life at home and at work and needs to demonstrate that it will be a force for positive progress. One issue, which will become dominant, is the need for sustainable development.

This represents a significant challenge to the entire construction community, its processes and technologies, as well as to its clients and customers who must demand buildings whose economics are considered on a whole life basis. R&D has a pivotal role to play here but the effort needs to be carefully focused on those activities in which the industry will invest either out of enlightened self-interest or to respond to the demands of clients and government policy.

To help provide this strategic thinking and orchestrate the dialogue, I have proposed new roles for the Strategic Forum and for the Construction Research and Innovation Strategy Panel (CRISP).

The industry and the public interest are inextricably linked and Government policies should reflect this.

As **regulator**, Government has a responsibility to establish a framework that anticipates emerging needs but protects a minimum building standard. Government should wholly fund the R&D required for this responsibility.

As **sponsor** for the industry, government policies should facilitate change but not impose or assume control. Business issues and a clear strategic vision should drive industrial R&D policies and practices. The Industry must be encouraged to provide the leadership to set a strategic vision and define its R&D needs.

As **client**, Government has a vital role to stimulate innovation by demanding better value and fitness for purpose from public buildings, and particularly to take account of the interests of the eventual users of these buildings.

The strategic framework for R&D should be owned and managed by industry. But in order to facilitate early operation of the relevant bodies the Government should provide the necessary foundation funding to enable the strategic thinking required, after which the industry should pay. Government would thereafter participate in and contribute to these bodies as the guardian of the public interest and as the industry's major client, providing clear representation of policy requirements on such issues as sustainable development.

A REVIEW OF GOVERNMENT R&D POLICIES AND PRACTICES

MAIN CONCLUSIONS

INVESTMENT (P.28)

- Current Government investment in construction R&D should be safeguarded
- Increase investment on R&D supporting:
  –Productivity
  –Value for public sector clients
  –Strategic issues

STRATEGIC VISION (P.28)

- Acknowledge construction's contribution to quality of life agenda
- Facilitate a strategic vision owned by the industry
- R&D priorities should be based on strategic analysis of the issues faced by the sector

MECHANISMS FOR CHANGE (P.29)

- The Strategic Forum takes pivotal role in strategic thinking
- New arrangements for prioritising R&D building on foundations laid by CRISP

COMMISSIONING RESEARCH (P.31)

- Define longer term programmes of R&D based on analysis of problems
- Procurement of R&D on merit, avoiding monopoly supply
- Encourage collaboration, ensure relevance to industry needs, institute strong quality control mechanisms
- Improve dissemination, evaluate impact, assess return on government investment

GOVERNMENT FOCUS (P.32)

- Tailor Government R&D procurement to reflect the various motivations for government support:
  – Regulator
  – Sponsor
  – Client
  – Policy maker

RESPONDING TO UNFORESEEN EVENTS (P.34)

- Don't maintain government funded research teams 'just in case'
- By procuring R&D on merit, encourage centres and networks of excellence

SKILLS AND RECRUITMENT (P.34)

- Excite researchers by defining programmes of work in terms of quality of life issues and sustainability
- Demand multi disciplinary teams, and more inter-change of people between industry and academe
- Centres of excellence will encourage deeper skills and help to recruit and retain research staff
- Facilitate high profile generalist construction qualification

RESEARCH BASE STRUCTURE (P.35)

- Encourage closer working between traditional construction research organisations
- Enhance intermediary role of traditional research base, including a remit to distil knowledge, from outside the UK and outside construction, for use by the UK sector

INNOVATIVE CAPACITY (P.35)

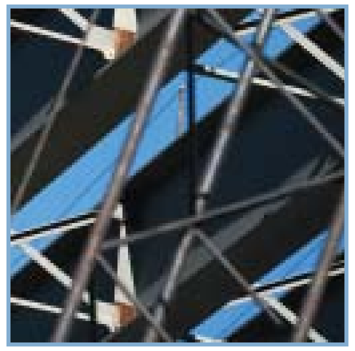
- Support the best innovators
- Encourage innovation by providing guidance and encouraging participation in the Teaching Company Scheme.

(iii) INTRODUCTION

This Review was commissioned by Nick Raynsford, the then Construction Minister in the Department of the Environment, Transport and the Regions (DETR), in May 2001. He wanted an independent view of what future role government should play in supporting construction research.

One of the main reasons for undertaking the review was the anticipated expiry of the Framework Agreement with the Building Research Establishment (BRE) in March 2002. BRE was until 1997 a part of the former Department of the Environment, undertaking research to support the Department's regulatory and sponsorship role. In 1997 it was privatised, with a five year guarantee of a minimum amount of work which it would be offered each year on an exclusive tender basis by the Department. Over the five years since privatisation in excess of 50% of the Department's expenditure on construction research was with the BRE under the terms of the Framework Agreement. The expiry of this Agreement therefore provided a stimulus to review arrangements for the future.

Following the general election of June 2001, construction sponsorship was transferred from the former DETR to the Department of Trade and Industry (DTI). The newly created Department of Transport, Local Government and the Regions (DTLR) assumed responsibility for building regulation. From June 2001 onwards, this Review was jointly overseen by both Departments. It provided a timely opportunity for consideration of how to maximise the benefits of the new arrangements for all the various construction stakeholders – clients (including government), the industry, the research base and the wider community. For that reason it was clear that the Departments would welcome a broader review than that set down in the terms of reference.



THE TERMS OF REFERENCE – A SUMMARY
(full details at Annex A)

To assess what research competencies and facilities government should help maintain in order to:

- provide scientific underpinning for the Building Regulations;
- be able to respond quickly to urgent concerns which may arise over the safety and health implications of buildings and structures; and
- support government policy to ensure a more competitive and sustainable UK construction industry.

To review the processes by which research priorities are established and research commissioned in order to recommend effective systems for meeting future demand.

To conduct a review of the research competencies and facilities currently available.

To make recommendations about the level and distribution of continuing support which DTI/DTLR should provide to support key competencies nationally;

To make any other relevant recommendations

THE REMAINDER OF THIS REPORT IS IN 3 PARTS (PLUS ANNEXES):

PART 1: BACKGROUND AND EVIDENCE:
Background information and evidence relating to generic issues raised by the Review:

PART 2: GOVERNMENT'S ROLE IN SUPPORTING CONSTRUCTION R&D:
This section asks why Government should support construction R&D. It goes on to specify four categories of Government support for construction R&D which are used to inform a more detailed discussion of the issues to be considered in framing future arrangements.

PART 3: CONCLUSIONS AND RECOMMENDATIONS:
Finally, the Report gives conclusions and recommendations for the future, which although aimed primarily at DTLR and DTI as sponsors of the Review, are also aimed at wider stakeholders in the industry and beyond.

PART 1

BACKGROUND AND EVIDENCE

1 ASSEMBLING THE EVIDENCE

The Review was undertaken between May 2001 and January 2002. Key individuals and representatives were invited to give their views in person and in writing - a full list of consultees is attached as **ANNEX B**. These submissions informed the findings of this report, and the individual discussions were extremely helpful in testing emerging ideas. A consultation meeting, held on 4 December 2001, provided a further sounding board and gave the opportunity to discuss the broad outlines of the Review's conclusions.

In support of this input, the Science and Technology Policy Research unit of Sussex University (SPRU) was appointed to provide underpinning analysis of the construction research base, attached as **ANNEX C**. This work involved a review of existing data sources indicating the nature, size and condition of the research base. It included analysis of the flow of new people into built environment higher education courses, the quality of construction-related university departments, industrial research publications and previous input-output analysis of the flow of research funds in construction. It also involved developing new databases using information held by DTI (formerly DETR) and the Engineering and Physical Sciences Research Council (EPSRC) – the principal funders of construction R&D.
A small-scale survey of connectivity between industry and the research base was implemented in the UK, and a survey of international experts was conducted to seek views on strengths and weaknesses in UK construction research. In addition, a workshop was held with Reading Construction Forum (RCF) representing a range of industry views, and in-depth interviews were carried out with senior people in construction research.

SPRU also contributed throughout the Review, helping to develop ideas and frame recommendations.

Several written inputs were requested, in order to provide an assessment of the key issues facing the industry, and how they might best be addressed in the future. Written inputs were received from the following (which can be viewed on the DTI and DTLR websites):

- Construction Research and Innovation Strategy Panel (CRISP)
- Co-Construct (collaboration between 5 construction research associations: Construction Industry Research and Information Association – CIRIA; Building Services Research and Information Association – BSRIA; Timber Research and Development Association – TRADA; Steel Construction Institute – SCI; and the Concrete Society)
- Building Research Establishment (BRE)
- Reading Construction Forum
- Institution of Civil Engineers (ICE)
- Construction Industry Council (CIC)

In addition, the building regulations division of DTLR provided an assessment of their likely future requirements for research to underpin the Building Regulations. Much of this work has traditionally been undertaken by the BRE. The assessment is a good model, showing how it is possible to plan requirements where research needs can be identified along strategic lines. Details are attached as **ANNEX D**.

2 CURRENT RESEARCH FUNDING AND PARTICIPATION

In 2000, construction produced about 5.2% of GDP, about 40% from the public sector (including the private finance initiative). If value-added produced from construction materials and related components is included, the contribution to GDP rises to around 8%. For example, construction draws heavily upon the products of mining and quarrying, upon manufactured components and parts, as well as other services. In comparison, manufacturing produced nearly 19% of GDP whilst mining and quarrying accounted for almost 3% and electricity, gas and water supply for 2%. Wholesale and retail produced nearly 16% of GDP and other services accounted for more than 46%.

Moreover, construction produces, maintains and adapts around 60% of all fixed capital investment. These are the buildings, structures and infrastructures upon which most other economic activities depend. The quality and efficiency of construction therefore has a bearing on long-term economic growth and industrial competitiveness in the UK and in export markets. Construction processes and the function, desirability, cost, sustainability and utility of finished products affects the quality of life of everyone living in the UK.

Construction thus impacts extremely widely. It does not simply affect those in the construction industry, but all stakeholders in the design, construction and use of built assets. A narrow definition of construction research cannot properly serve the future needs of the sector and its stakeholders, and for this reason the Review as a whole has taken a much wider view of construction's contribution to the UK economy and quality of life.

2.1 Public funding for construction research

Over the last 10 years public funding for construction research has been, in total, between £50 and £70m annually. Funds for construction research are spread between several organisations, although the former DETR Programme and that of EPSRC provided the bulk of it:

- DTI (formerly DETR) – encouraging national and international competitiveness and health of the industry, and improving its ability to harness the benefits of science and technology and to develop its own capabilities. Support of applied research with direct relevance to a number of constituents within the sector.
  Funding from DTI's programme is currently around £15 - £18 m annually.
- DTLR (formerly DETR) - protecting and enhancing issues of public interest, including the making of building regulations. The regulations cover building design and construction to ensure the safety and health of people in and around buildings as well as the energy efficiency of the built environment. Support for testing and development of materials and systems of relevance to public policy-making. Funding from DTLR's Programme is currently around £6m annually.
- EPSRC - supporting the engineering and physical sciences research base, including engineering and production management, primarily in Universities. It aims to:
  a) develop new knowledge;
  b) train new people for industry, public and non-governmental organisations and for research careers; and
  c) build public trust and confidence in the benefits of new technology and scientific discoveries.

Around £25m was awarded to construction research grants, with a larger sum being invested in research of relevance to construction. The main programmes funding construction-related research are: Innovative Manufacturing, Environment and Infrastructure, and General Engineering. Newly established programmes such as Sustainability and the Urban Environment will also be of significance.
In 2001, EPSRC established new funding mechanisms to consolidate research in the Innovative Manufacturing Programme.
In the initial round, three Centres for research in construction were established at Loughborough, Reading and Salford Universities.

- There are other sources of funding for research relevant to the construction sector. The Economic and Social Research Council (ESRC) funds some research of relevance to construction in management and in projects on social issues and economic geography (e.g. cities and urban development). The total investment of direct relevance to construction research, broadly defined, is between £2-£3m annually.
- Other agencies promote research that has relevance to the construction industry, for example public funders such as the Highways Agency, Environment Agency, and Housing Corporation, and charitable or non-profit distributing bodies such as the Foundation for the Built Environment, the Joseph Rowntree Foundation and the Ove Arup Foundation. Programmes jointly funded by the Research Councils, for example the Tyndall Centre on Climate Change, are also important. The contribution of all these agencies relates to construction research - broadly defined as production and use of the built environment.

Public investment in construction research needs to be seen in the context of the total national expenditure on construction each year of some £64bn, and public expenditure on construction procurement of about £25bn. Sir John Egan's construction task force report 'Rethinking Construction' concluded that annual improvements of 10% in value were achievable year on year. Suitable R&D will be needed to make this happen. Current public investment in construction research represents less than 3% of potential annual savings to the exchequer.

2.2 European funding

European Framework Programmes are a significant source of research revenue for the UK. As a rule of thumb the UK wins around 14% of EU research funding. No measured record is kept of UK construction's share of funds, but the EU is perceived by a number of players in the research base, and a very few companies, as a major source of funding.

2.3 Research base: independent research organisations

The non university sector for construction is dominated by BRE. BRE was established in 1927 to test materials and components and raise construction standards. It has traditionally provided independent advice to government policy makers. Since privatisation in 1997, it has received 64% of former DETR construction R&D funding, amounting to about £80m.

The review found general support for the role of BRE, and for the view that any new arrangements should allow BRE to thrive - on merit - in the future.

Another key element of the research base is represented by the member based research associations. The main recipients of DTI/DTLR funding outside the BRE are: Building Services Research and Information Association (BSRIA) 4%; Construction Industry Research and Information Association (CIRIA) 4%; Timber Research and Development Association (TRADA) 3%; HR Wallingford 3%; Steel Construction Institute (SCI) 2%. Over recent years government has supported a partnership of CIRIA, BSRIA, TRADA, SCI and the Concrete Society, who now have a joint web presence and collaborate under the name Co-Construct.

Co-Construct and their membership have found competition for research funds skewed by the BRE Framework Agreement. The Framework ends in March 2002. This means that a new accommodation will need to be worked out between BRE and the Research Associations to ensure a strong and thriving independent research organisation base for construction.

2.4 Research base - universities

The university sector and the construction industry have traditionally been poorly coupled, and there is evidence that the industry at large is still wary of academics. Since the introduction of EPSRC's Innovative Manufacturing Initiative (IMI) seven years ago the coupling has improved, and the major university construction research departments are now working directly with the most enlightened industry players. So, from a low base, the position is improving. There is nevertheless much potential for the industry to engage more actively with academe in the future, which government R&D procurement arrangements should do more to encourage.

University research funding for construction comes principally from the EPSRC. The funding is more evenly distributed amongst the largest receivers (29 Universities received more than £1m in the last 4 years, compared with 8 organisations funded by DTI/DTLR receiving more than £1m in the same period). Nevertheless, the university construction research base is more fragmented than in many other subjects, with 85 universities being recipients – many of them of relatively small amounts of funding. Research conducted at universities tends to be focused on longer-term problems and development of new ideas.

This sector trains new people, providing future practitioners and researchers for the industry. However the number of applicants to built environment disciplines has declined dramatically in the past 6 years during a period when student numbers across all disciplines have risen.

2.5 Incentives for collaboration between industry and academe

In the past, funding and assessment of academic research has not helped to incentivise interdisciplinary working, nor has it helped to incentivise industry-relevant research. Although there has been more emphasis, for example in the Research Assessment Exercise (RAE), on collaboration with industry, evidence is inconclusive as to whether there has been a substantive change in attitude in the construction research field. The key point to stress is that much more collaboration between industry and academia is required if the industry is to properly benefit from university ideas and expertise.

2.6 Research within construction companies

Research carried out by the business sector is measured as Business Expenditure on R&D - BERD. Total BERD carried out in the construction sector is very small for the size of sector. In 1999 construction BERD was £40m per annum (ONS data).

Research and innovation in construction often occurs through design and engineering processes or problem solving on projects and this 'investment' is not calculated in BERD.

There is also an issue about the industry's capacity to absorb innovation and new research knowledge. The best in the industry are as good as any in the manufacturing sector at undertaking and gaining knowledge from research. But they are in the minority. Of the 160,000 contractors operating in the UK, fewer than 20,000 employ people with higher technical qualifications and only around 200 employ 5 or more people with such qualifications. Some of these companies may appreciate the need and have a desire to innovate, but if they are typical of the industry then their size and composition make it difficult. The rest are simply too small or too preoccupied with survival to engage in R&D in a meaningful way. This does not mean that the R&D agenda is irrelevant to these businesses – there is probably more scope to improve the quality and image of construction by innovation and change in this most conservative segment of the industry than in any other. What it does mean is that these businesses cannot be expected to engage with a strategic research agenda – instead they require targeted help to improve, including distillation of information on new practices. This is currently delivered by several means, including performance-based building regulations and the Construction Best Practice Programme.

Industry championship and leadership of research is a good indicator of high impact projects, and of positive returns to the collaborators. It is generally accepted that R&D intensity in businesses is positively correlated with company performance. Innovation gained through active collaboration in R&D projects has a better chance of becoming embedded in company practice than innovation invented 'over there'. For all these reasons, government procurement of R&D should encourage more construction companies to engage positively in collaborative research, and maintain investment with the best companies that are already engaged with the research programme.

2.7 DTI/DTLR funding summary

In total, DTI/DTLR have funded 172 organisations during the past 4 years. 164 of these were recipients of just 19% of the funding, representing a wide distribution, mainly of small projects carried out in a fragmented research base. This can be seen as both a strength and a weakness. On the one hand it has perhaps spread funds too thinly, not allowing any centre except BRE to build up the critical mass and long term funding to make a real difference. On the other hand, by funding a large variety of different organisations the DTI/DTLR schemes encouraged many firms to get engaged in construction research, and provided funds for some small, new and arguably more innovative organisations to join the research base. New arrangements for procurement of R&D must encourage critical mass and centres of expertise where appropriate, but must also allow for some adventitious and innovative work on a more flexible, reactive basis.

The BRE Framework arrangement has reduced options about where government should procure R&D in the sector over the last 5 years. There is now an opportunity to refocus government support, towards a vision of future excellence in R&D procurement that will satisfy government's various needs as well as safeguarding the health of the construction research base. In doing so, there should be a conscious effort to further improve the coupling of academic research to the needs of industry, and to increase the capacity of industry to absorb the outputs of academic research.

3 INDUSTRY'S STRATEGIC ENGAGEMENT WITH GOVERNMENT FUNDED R&D

The review found too little evidence of clear ownership of policy or future R&D needs by industry bodies. Industry seems to expect Government to provide policy and strategy. But there is a strong case for policy and strategy to be owned by the industry itself, with a clear role for government as major client and guardian of the public interest. Leading industry players should grasp the opportunities set out in this report and take a more proactive role in debating and setting the research and innovation agenda.

3.1 Fragmentation

The fragmented nature of the industry seems to have played a large part in making construction reliant on government leadership.

- The industry is characterised by a large number of relatively small firms, a large number of relatively small construction projects, and low barriers to entry, particularly in the (small) contracting sub-sector.
- The industry is fragmented because of the many disciplines involved – designers, constructors, professional consultants and engineers, and specialist contractors. It is fragmented because of long and complex supply chains, bringing together the different specialists. Low profit margins combined with traditional procurement in construction led to adversarial relationships and poor service to clients. Construction is differentiated from much of manufacturing industry by the form its product takes - in terms of its long life and inseparability from the real estate it occupies, and the time taken to design and construct it.
- The endemic fragmentation is exacerbated by the defensive stance of the various professional institutions which strictly maintain their independence, in the process discouraging the development of multi disciplinary skills.

PART 1: BACKGROUND AND EVIDENCE

One of the consequences of fragmentation is that the sector lacks a vision – about its role in society and about how to better serve its customers and wider stakeholders. It does have an excellent blueprint for process improvement within the industry – Sir John Egan's report 'Rethinking Construction'. This was written to help the industry solve some critical immediate problems, and is helping to lead companies towards a more customer centric way of working. Rethinking Construction has been widely accepted, is beginning to have a profound influence on the industry, and has helped to bring forward and encourage innovation. But it is not the whole story. There is a wider debate needed about the role of the construction industry in creating a better quality of life for everyone, which the industry needs to grasp and lead.

3.2 Priority setting

The former DETR's construction research programme had at its heart the twin aims of supporting the Rethinking Construction initiative and promoting more sustainable construction. It included a very wide ranging portfolio, details of which can be found in **ANNEX C**. There was a commendable emphasis on consultation with industry, and priorities were directly influenced by the work of the Construction Research and Innovation Strategy Panel (CRISP) and the Building Regulations Advisory Committee (BRAC). The main funding mechanisms have been the BRE Framework Agreement, Partners in Innovation, LINK and – recently – a new pilot scheme to capture innovation from real time construction projects called Fast Track.

3.3 Industry involvement in priority setting

In recent years the government provided CRISP with funding for a small secretariat and a budget to allow it to commission consultancy studies in support of its work. CRISP's remit from government was to help to define the R&D needs of the construction industry, to feed into the DTI/DTLR Programme and to influence other funders. It has succeeded, with limited resource, to articulate research requirements in several key areas, and has developed a successful modus operandi involving short term task groups convened to tackle particular perceived problems, identify gaps in research and advise the relevant research funders. Its achievements have been as a result of the considerable time and effort which a small but committed group of industry representatives were prepared to devote voluntarily to its activities.

But CRISP has its limitations, which are generally acknowledged. It is still not well known across the industry. It has found it difficult to generate wider interest and buy in from the industry. And it is sometimes perceived as having been too open to influence by vested interests.

Despite this, CRISP represents a real attempt to develop a pan-industry strategy setting body for construction R&D. The industry should build on its achievements, increase CRISP's visibility and seek to provide it with a strong mandate to help construction think about the future.

There are many other panels, networks and clubs. Some have particular constituencies – for example the Reading Construction Forum, European Construction Institute, CIC's R&I Committee, Construction Productivity Network. The member based research associations also bring powerful networks to bear. Industry engagement of this sort is extremely important, and should be built upon. But it is also vital that the various bodies work better together for the common good, and complement one another's efforts.

3.4 Strategic Forum

Fragmentation of the industry, with its byzantine maze of representative bodies, has made overall strategic dealings with government problematic. The recently created Strategic Forum, chaired by Sir John Egan, offers a new opportunity of bringing together the representative umbrella bodies and the Rethinking Construction innovators, and could have a significant role to play in leading the agenda for R&D.

3.5 A challenge to government and industry

The lack of a long term research strategy for the industry means that the overall framework within which funding decisions are made tends to be disjointed. Some strengthening of horizontal mechanisms across the board, including between research funders, is therefore required. Multiple research funders are not unique to the construction industry, but the industry could get a better deal overall by acting more coherently and taking responsibility for its own research agenda. With such a fragmented industry (much of it comprising small organisations without the capacity to engage with strategic research issues) it is for the major players, and those prepared to innovate, to take the initiative and engage in setting the longer term research road map.

4 ENSURING SKILLS FOR THE FUTURE

A key question is whether the industry, and the research base that supports it, is in a position to provide the leadership and vision needed to bring about the next step change in the industry's performance. Clearly the UK has world beating construction businesses. For example leading UK consulting design and engineering firms have enjoyed a successful period of growth and are world leaders in several specialist areas.

4.1 Supply of professional skills

But there are well reported problems. There is considerable concern that the supply of professional skills required in the production and maintenance of the built environment has not matched the changing needs of the sector. Moreover, there has been a dramatic decline in the numbers of new entrants on construction-related degree courses. If the current rates of decline were to continue into the future, the number of students in the built environment would rapidly collapse. By 2009 the number of applicants to civil engineering courses would have fallen to 0, while the last applicant to building and construction courses would enter university by 2012. So far, the declining trend line shows little sign of bottoming out.

The industry needs to find a way of attracting and retaining bright people - including the widening of its appeal to women and other under-represented groups. This problem is widely recognised – recent reports commissioned by the Arup Foundation set out the issues. The 'Respect for People' initiative focuses on wider 'people' issues, and includes recruitment, retention and respect as its core themes. But all this good work needs to be built on and the momentum sustained. The industry needs to ensure that it is training and retaining the strategic leaders of the future.

Part of the issue is that the industry is attempting to attract its new blood into the same old silos – taking the problem back to the issues of fragmentation and the need for more multi disciplinary working. This system of silos within the industry, within the engineering profession and academia is failing to attract bright young people; a view broadly shared by most of the contributors to this review. It is essential for this problem to be tackled or the industry will atrophy. The industry must attract people to its ranks who are challenged by the opportunity to make a difference – make a contribution to a strategic vision. The Institute of Management's recent report '*Leadership – the challenge for all*' shows that inspiration and strategic thinking are rated as the most important attributes of leadership by most managers. But so long as the careers on offer in construction are narrowly based, with limited horizons and modest rewards, bright young strategic thinkers will turn away.

There is an urgent need to create a career path that provides a broad qualification across the whole process of design, environmental planning, project planning, construction and beyond, to create a cadre of potential leaders for the industry. The final academic qualification for some would be an engineering doctorate presently offered by the EPSRC.
But other, more flexible ways of providing such a broad based qualification should also be established. This more generalist career path would not replace but be in addition to the development of existing specialty skills.
It could perhaps be billed as a prestige entry for fast path development. Commitment from consultees to this concept seemed strong, but real action is now required. The current leaders of the industry need to demand a system that provides more broadly qualified people, and support them properly so that the brightest and best have the incentive to seek such qualifications.

4.2 Research skills

Graduate and post-graduate skills shortages in the industry lead to skills shortages in construction R&D. Again, the key question arises – is the construction research base in a fit state to tackle the most critical issues of the 21st Century? Does it have the right people, the right organisation, the right vision? Does it have the right skills? This review has found that there are some excellent centres undertaking research, but that there is also room for improvement – the research base is fragmented, patchy in quality and in size. For reasons already outlined above it will find it hard to attract people of the right calibre in the future.

This is very serious. Industry does need to engage energetically with the R&D agenda. But it must simultaneously tackle the skills issue – bright people are needed to push innovation in the industry. The potential lack of high calibre personnel being trained to work in UK construction is the greatest threat to the long-term health of the research base.

A supplementary issue is the trend for overseas students to take a larger proportion of construction education and research places in the UK. This is not a problem for the quality of education nor of research. But when overseas students return home with expertise gained in the UK, the supply of high quality potential employees for the UK based industry is inevitably reduced.

Government procurement of research for construction has a role to play in helping to tackle skills shortages in construction research, by providing a more coherent and longer term focus for work and allowing more certainty of employment for those undertaking R&D. People who are skilled in longer term, strategic research are not always able to shine in a shorter term, more tactical 'consultancy' environment, although there are of course exceptions to this generalisation. However, procurement on a project by project basis fails to provide the security, continuity and critical mass to encourage longer term work programmes which help to develop in-depth research skills.

4.3 The role of Professional Institutions

The Professional Institutions have historically played a role in accrediting professional courses for the various construction disciplines (which help to dictate the shape of university departments, and affect the nature of research that is undertaken within them). Each Institution jealously guards its autonomy. This was identified as a barrier to interdisciplinary working by many of the contributors to the Review.
It is evident that construction research will, in the future, increasingly need people who are comfortable working across disciplinary boundaries. Professional accreditation needs to move towards fostering and promoting, rather than inhibiting, the development of such skills.

It is beyond the scope of this review to do any more than state that the Institutions must address this issue and provide much better mechanisms for enabling inter- and multi-disciplinary qualifications. In order for this to happen, practioners in the industry must demand that the Institutions take action. This is not to say that the narrower focus that individual institutions bring to their specialisms is not also required – qualifications and research should be undertaken within a framework that allows both breadth (cross-discipline) and depth (specialism), depending on circumstances.

5 THE INTERNATIONAL DIMENSION

The international dimension to research and innovation in other countries did not form a substantial element of input to this Review – it tended to be raised as an afterthought if raised at all. Differences in climate, materials availability, legal frameworks and living patterns to some extent constrain the international transfer of construction technologies and practices, but much research in other countries will be relevant to the UK. Both research bodies and construction firms should therefore be aware of developments elsewhere that could be exploited in the UK (or in export markets).

The construction research base has well established networks for international exchange of information. Collaboration in joint projects has been encouraged in the past decade by the creation of new funding mechanisms, notably the Framework Programmes of the European Union. BRE and universities have been prominent in European programmes but construction firms (with some notable exceptions) have been poorly represented. Those construction companies that have been deeply engaged are clear that the technologies that they have developed through participation in European programmes have brought commercial advantage. But the industry in general has not benefited from the European funding that has passed to universities and research centres; as with other R&D engagement, the main benefit comes from collaborating and taking part.

Innovation may be stimulated by awareness of international experience and practice, without the need for formal research. Awareness of advanced practice in other countries has developed in some areas; for example, new approaches towards housing technology have been stimulated by the reports from DTI-assisted missions to Japan, North America and Europe. Some international firms use their overseas operations as sources of technological innovation. But generally the UK construction sector does not look outside its national boundaries for new ideas and technologies.

Accordingly, one feature in the new arrangements should be a much stronger effort to tap the world's investment in research and innovation, through such measures as scrutiny of technical reports, active collaboration in international projects, exchanges of staff, fact-finding missions and invitations to leading international practitioners. The principal centres for construction research should have an explicit remit to be capable of presenting the best of the world's research and practice to their UK clients and partners. Moreover, research should be of international standing, for this enables researchers to appraise the quality and relevance of outputs from other countries' programmes, and programmes should be evaluated from an international perspective.

PART 2

GOVERNMENT'S ROLE IN SUPPORTING CONSTRUCTION R&D

PART TWO of this Report focuses on the role of government in supporting construction R&D, and on the four main categories set out below. For each, it sets out the main issues faced, the current position, and a possible way forward. It is recognised that some R&D would serve several interests. There was already a need for better horizontal mechanisms, which has become more important since the split of the old construction directorate between DTI and DTLR. Whilst consideration is from a DTI and DTLR perspective (as sponsors of this review), the needs of the rest of the public sector – as clients and policy customers – are acknowledged and taken into account.

4 MAIN CATEGORIES OF GOVERNMENT SUPPORT:

- R&D to support the government in its role as **regulator** – which is primarily to underpin the Building Regulations, but also includes work to help understand wider issues of safety and health in and around buildings
- R&D to support government in its role as **sponsor** of the construction industry
  - to support innovation and competitiveness. Innovation is defined here as 'successful exploitation of new ideas leading to profitable change', and includes work to support the broad agenda of Sir John Egan's 1998 report 'Rethinking Construction' and the initiatives that followed it. Alongside the competitiveness agenda, R&D is needed to ensure better exploitation of academic innovation within the industry.
  - tackling issues of strategic importance, and stimulating the industry and its stakeholders (including the public sector) to articulate a vision for the future and a research strategy to lead it there.
- R&D to help government fulfil its role as **client**, on behalf of the public sector as a whole, in order to derive best possible value for money.
- R&D to help government more generally in its role as **policy maker** for issues that directly affect, but go wider than, the construction industry (for example energy efficiency and climate change). It would also include R&D to react to unforeseen circumstances and emergencies.

6 GOVERNMENT'S ROLE IN SUPPORTING CONSTRUCTION R&D

Contributors to the Review thought that government played a particularly hands on role in sponsoring and challenging the construction industry to improve. Moreover, the industry was perceived as weak in putting its own case, even by its own representatives.

The four roles set out here – regulation, sponsorship, client, and policy maker – all provide good justification for government intervention in construction R&D. Government acts as guardian of the public interest in ensuring safety and health in and around buildings through the Building Regulation system. But there is a wider public interest argument. Virtually all businesses in the country rely on the construction industry to provide and maintain their accommodation, plant and infrastructure, and everyone has experience of construction because of where they live, work and play. Positive Government engagement aiming for improvements in the quality of design and construction, in the value and sheer enjoyment of the built environment and in a more sustainable future, serves everyone's interests.

More specifically, Government is the dominant client of the industry, the public sector represents about about 40% of construction's turnover (about £25bn) annually. It is therefore in the Exchequer's interest in a narrow sense, as well in the wider one described above, to put effort into improving construction. The R&D agenda needs to support this push for general improvement.

For all these reasons, the Government should promote a strong and vibrant construction research base. SPRU have noted the way that privatisation and competition has changed relationships between research bodies – they are tending to collaborate less with one another than in the past. Some rebalancing of funding mechanisms to encourage more collaboration between research providers, as well as the already noted need for encouragement of industry involvement in research is required.

7 GOVERNMENT AS REGULATOR

The Building Regulations provide performance standards for the 'as built' design of buildings with regard to the health, safety, welfare and convenience of occupants. They cover new build, some refurbishment and alteration work, and change of use to existing buildings where this involves modifications to building design. The Building Regulations are underpinned by a set of Approved Documents providing non-prescriptive and increasingly performance based design guidance that is open to interpretation and encourages the uptake of innovation. The construction process and post occupancy issues are not explicitly covered but actual experience and research in these areas is taken into account to ensure design standards set by the building regulations are appropriate in the broader context.

The Building Regulations Division of DTLR needs to call on research competencies to fulfil requirements which have traditionally been sourced from the BRE. Although BRE is widely respected, and has particular strengths in many areas relating to Building Regulations, it must in future win work without any special government support or favour.

7.1 DTLR's needs can be broadly defined as follows:

- Develop sound scientific evidence in support of reviews and amendments of the Approved Documents;
- Represent and promote UK interests in the development of national and international codes and standards referenced in the Approved Documents;
- Assess the performance of new technologies or design solutions to ensure that the Approved Documents are kept in line with technological progress.

7.2 Demand for research competencies

DTLR's demand for research competencies depends on three main factors:

Approved Documents

The scheduling of revisions is set by DTLR and endorsed by the Building Regulations Advisory Committee (BRAC) according to Ministerial requirements, the pace of technical change and the extent of issues arising. The demand for research competencies relating to a particular AD tends to be higher prior to and during its revision. Knowledge and understanding of the technical basis of each AD needs to be retained and this requires continuous maintenance of the research competencies.

Development of new and revised codes and standards

DTLR needs to influence and respond to the activities of codes and standards development committees where these impinge on the development of practices and products that are covered by the Building Regulations. Some of this work is done in-house, but much is contracted out at present. Research competencies are particularly required by DTLR in those cross cutting areas that are not well represented by industry bodies (eg trade associations). European harmonisation work is creating a high demand in the short to medium term for the research competencies required to establish correlation between emerging European standards and the existing British Standards. The current focus is on fire, but work will be needed for all Parts of the Regulations as the relevant new European standards are published. In the longer term the demand for research competencies is expected to focus on revisions required to address developing technologies. Influence over European interests requires the availability of highly experienced individuals who bring research competencies and practical experience in industry.

Introduction of new technologies and design solutions

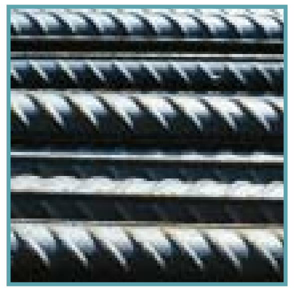
Economic considerations, and the extent to which these are influenced by the government's sustainability policy, largely drive the introduction of new technologies and design solutions. Demand is expected to increase for research competencies that can assess the performance and limitations of those innovations that impinge on the requirements of the ADs. Research competencies may emerge in association with an innovation but independent sources of expertise that can make impartial assessments may be more difficult to obtain.

7.3 Associated competencies

Besides research competencies DTLR require some associated competencies to drive forward and feed back on regulation change. These competencies include the drafting of AD revisions and codes and standards, development of regulatory impact assessments, the provision of professional advice on change take up, presentational and government representation skills, etc. Whilst such competencies are required generally, they are normally applied against specific technical issues and therefore need to be available concurrently with the research competencies.

7.3 Impartiality

DTLR require research competencies that are demonstrably impartial. Those residing in organisations that have vested interests in the application of the Building Regulations cannot be used. Trade Associations, Research Centres, Universities, etc may have particular interests and may undertake commercial research for the construction industry and product suppliers. The extent to which they will be perceived to be impartial needs to be considered on a case by case basis. As a result research competencies may frequently need to be drawn from more than one source to ensure independence and objectivity.



7.5 Main Topics

The Approved Documents, the codes and standards they reference, and the innovative technologies and design solutions that are assessed against the building regulation requirements cover numerous technical issues and require a very wide range of research competencies. However there are strong synergies between the technical issues and hence required research competencies for some ADs. There are three largely distinct areas addressing:

- Integrity of the building.
- Operational performance of the building.
- Occupant interactions with the building.

For each of these areas the specific issues that are expected to drive DTLR's requirements for research competencies over the next 5 years are summarised in **ANNEX D** . Government has defined the capabilities and expertise to which it needs access and should publish the terms for contracts for their provision to which bids will be invited from any independent research provider. It should be noted that it is unlikely that all the skills and resources needed to satisfy a particular requirement will be physically located together – it should not be necessary. It is accepted that a 'networked' arrangement will often satisfy the requirement so long as there is a prime contractor.

7.6 International

Where appropriate research is commissioned to consider experience from overseas, and how it might be utilised in the UK. Such research is usually commissioned as part of a review of a particular Part of the Building Regulations.

DTLR will be in the lead in taking forward new arrangements for supporting public interest research relating to regulatory responsibility, although there will need to be close cooperation with those in DTI responsible for sponsorship of construction.

Summary of key issues:
R&D in support of regulation

PLANNING

- government to identify priorities (**SEE ANNEX D**)
- government to define need for particular programmes of work, in consultation with expert help from the industry (Building Regulations Research Advisory Group - BRRAG)

PROCUREMENT

- procurement of work in each area needs to allow sufficient critical mass to allow researchers to plan longer term for facilities and manpower and create centres of excellence – so procurement must be on the basis of programmes of work rather than individual projects
- research base needs to provide the right mix of skills, which may require far more networking than previously.
- Impartiality of research teams must be maintained
- excellence from abroad should be utilised where appropriate, perhaps by incorporating overseas partnerships
- award of work needs to be on the basis of competition rather than preferred supplier (which happens at present with BRE), although the awards should be for as long a period as possible within the constraints of government spending rules.
  One model could be a 2 stage bidding process: the first responding to a request from government for provision of a programme to tackle a particular problem/area of work; the second a more honed proposal responding to a refined tender request from government which would take into account the ideas put forward in stage 1
- Some competition should be maintained throughout– government should not create monopoly providers

MONITORING

- quality control and ongoing impact assessment will be required – regular review needs to be built in
- management should be rigorous, advised by an expert steering group

EVALUATION

- evaluation should be undertaken regularly, focused on the desired outcomes of the Regulation, and how the underpinning research contributed to its original remit

8 GOVERNMENT AS SPONSOR

Government's aim as sponsor of the construction sector is the improvement of productivity, competitiveness and innovation. Sponsorship activities and research support should in the future be more closely tied into the generic sponsorship activities and models which DTI makes available to other industry sectors. The new arrangements will provide the additional benefit of greater opportunity for learning across sectors. Much of what the industry has needed and will continue to need is learning and adaptation from other sectors. It is important that the new arrangements for research support should recognise this. Advanced applied research has its place in construction as in other sectors, but technology transfer and management of processes will continue to be as, if not more, important in influencing improved performance.

8.1 Competitiveness and innovation

Sir John Egan's report 'Rethinking Construction' provides the backdrop to much of the DTI policy support for the construction industry, and – alongside sustainability – is the major plank of the DTI part of the construction research portfolio. Most of the priority areas for research under Partners in Innovation relate very closely to the Egan agenda and to sustainability.

Following publication of 'Rethinking Construction', the government set up a ministerial steering group to oversee the implementation of the Report through four principle working groups – the Central Government Task Force, the Local Government Task Force, the Movement for Innovation and the Housing Forum. These initiatives have since come together under the banner 'Rethinking Construction'.

Rethinking Construction, and in particular Movement for Innovation and Housing Forum demonstration projects, represents a new model for driving innovation in the industry. It is too early to quantify success, but indications are that performance on demonstration projects is better than in the industry at large, and there are certainly positive messages about industry involvement and action embedded in the Movement.

Recent work by CRISP on behalf of Rethinking Construction has highlighted some interesting outcomes from demonstration projects. These include that taking part is generally perceived as the greatest benefit. Results and outcomes, when written down, are often distrusted. With a few notable exceptions, knowledge transfer does not tend to 'ripple' out from members of project teams to their companies or other organisations. CRISP recommends that more time and effort needs to be expended on learning the lessons from demonstration projects, that rigorous validation of benefits is crucial and that organisations need to consciously develop a 'learning culture'. Rethinking Construction has commissioned further work designed to improve both the demonstration process and demonstration project outcomes.

PART 2: GOVERNMENT'S ROLE IN SUPPORTING CONSTRUCTION R&D

8.2 Standards

The industry lacks robust arrangements to develop industry standards - agreements between competing companies to adopt a standard approach for the benefit everyone. One important example cited during the Review was the need for standards to define interfaces between prefabricated modules and components. Such standards provide economy of scale for suppliers and act as powerful productivity drivers. They contribute to institutional learning. There are many areas where industry standards could make a significant contribution. The implementation of some of the Egan recommendations will depend on the establishment of 'standards'.

Generally, this is an engineering issue and professional engineering institutions can play an important role in bringing all the right parties together on neutral territory. In other industries, the Internet has been used effectively to link committee members to speed the convergence of opinion. This is an important competitiveness issue where some facilitation by government might be appropriate, but where real progress will only be made when the major industry players get together and force the issue through, in partnership with their major suppliers and in consultation with their major clients – and when they are jointly prepared to pay for R&D to help make it happen.

8.3 Well-founded R&D depends on analysis of the issues

An important finding of this Review is that Government procurement of research in support of competitiveness must be tied more clearly to an analysis of the problems facing the sector, which will be informed by dialogue with the industry leading to consensus on key issues and priorities. A firmly based analysis of the issues must be made in order to provide justification for R&D programmes and ensure industry relevance. Industry leaders must play their part in defining the issues.

Issues need to be prioritised in a way that allows programmes of research work to be defined to tackle them. Project by project funding is unlikely to provide sufficient focus or critical mass to make real inroads into the most important problems facing the sector, although the Department should not rule out procuring individual projects to fill particular gaps or take advantage of particularly innovative thinking. Defining research problems into larger programmes would have the additional advantage of allowing enough 'critical mass' for research contractors to bring together integrated, multi disciplinary teams and ensure that all the various stakeholders within the programme are well informed about progress. Industrial engagement and championship is particularly important, and industry collaborators must be prepared to contribute at least half of the resource needed to fund programmes of work.

8.4 Management

In recent years DTI and DTLR (when together as the former DETR) employed consultants to help them run the construction research programme. These research management contractors (RMCs) were needed to help manage the large and varied portfolio of projects under both BRE Framework arrangements and the Partners in Innovation scheme. Over the last 4 years, a total of 1064 projects were let across the whole DETR portfolio, managed under business plans and latterly themes. The key RMC contribution to date has been in bringing additional resource, beyond that available in the departments, to bear on management of projects: milestones, steering group arrangements, and a better focus on exploitation and dissemination. In the future, any RMC contribution will need to take a more strategic role in helping to define and oversee programmes of work, ensuring strong quality control and ongoing relevance.

A key aim should be to disseminate the knowledge gained from the programme in a way that maximises its potential benefit by influencing the way that companies behave.

8.5 Emphasis

Government should invest where the potential for real world impact and added value is greatest. It should place emphasis on embedding innovation and lessons learned from research into the way companies work. Some refocusing of research funding is needed, perhaps using two overlapping headings:

- R&D to support the leading industrial players to develop and drive innovation further into their own, and their supply chains', businesses.
- advice and help to the rest of the industry and its stakeholders – aimed at embedding innovative ideas in order to improve the quality, value, customer focus, and sustainability of UK construction as a whole.

8.6 Strategic longer term vision for the industry

Construction has a key role to play in society in providing a better built environment, but has been poor at convincing itself and other stakeholders that this is so. If it is to address the skills crisis and attract young people it needs to be seen as central to a better quality of life for everyone, and concerned with a sustainable future. It needs to develop its vision, get widespread buy in and communicate it to all stakeholders. As already noted, a proper analysis of the longer term issues facing the industry (from which programmes of research can be articulated) is essential. The research agenda needs to support this vision, and government should facilitate it as part of its sponsorship role.

8.7 Existing mechanisms for strategic thinking.

There are some existing mechanisms to tackle strategic and longer term issues for the industry, but on the whole it has to be said that the construction industry has not taken to heart the need for longer term and strategic thinking. The energy, resources and intellectual capacity devoted to consideration of construction's future are inadequate.

The Strategic Forum has been established as a representative forum for the industry, and although its initial aim is to drive forward the Rethinking Construction agenda, it is well placed to widen its remit to tackle longer term issues.

The recent Foresight exercise included a specific report on the future needs of construction, but by concentrating on the needs of the industry itself, its focus was on operational effectiveness rather than wider vision and strategy. The generic Foresight process itself will now be refocused onto exploitation of new technologies rather than sector specific work, so Foresight will no longer provide a tailored route for strategic thinking for construction.

The current construction research portfolio contains some longer term work - for example in the field of sustainable construction – which helped to inform the report 'Building a better quality of life' and other initiatives. Sustainability in its broadest sense is given priority - it is the main driver of the current construction research programme - but it should be more coherently articulated and broken down into a clear framework to clarify the various strands of work (what is already being done and where, what more is needed) and their contribution to the overall aims of economic, environmental and social sustainability. Sustainability is by definition customer/society centric, and provides the construction industry with an opportunity to create a vision with which society and particularly bright young people could identify.

8.8 The way ahead

It is critically important that a better mechanism be developed for defining the industry's long term research needs, embedded within a process for wider strategy setting. It is also critically important that there is clarity between government funding responsibility, and issues where industry itself should pay.

Procurement of longer term research and the setting of a strategic framework are the weakest links in the current government R&D procurement arrangements, but there are many building blocks already in place that could be mobilised and focused on future strategy. The workshop held on 4 December as part of this Review confirmed the importance of an industry-led strategic framework to drive the R&D agenda. It also confirmed the view that this would only happen if there was greater commitment on the part of industry leaders to a strategic vision for the industry and its place in society, leading to real demand for better articulation of the R&D agenda.

A representative industry body needs to provide strategic vision and leadership. Upstream the industry should engage with those of influence over the wider built environment, such as CABE, to clarify the contributions construction needs to make towards the overall quality of life agenda. Downstream, there should be a strong organisation providing a supporting role and an R&D focus.

Current input to the Strategic Forum and CRISP, apart from the limited studies commissioned by CRISP, relies on voluntary effort. It seems unlikely that the strategic thinking that construction needs can be undertaken on this basis within a realistic timescale.

As well as helping to set the forward research agenda, new arrangements must include raising awareness of futures issues within the industry, by engagement with the media, by publishing and presenting at workshops and conferences, and by utilising existing industry networks and delivery mechanisms. This would, of course, include networks and institutions beyond the UK.

An R&D agenda derived from a strategic framework would allow industry leaders to engage with all research funders, not just DTI/DTLR, and enable them to better prioritise their own investment in R&D as well as help define public funding. This is one reason why the initiative needs to be owned and driven by the industry, not by one government department.

A vision of the future, with a research strategy to signpost future gaps in knowledge in a coherent way, is an essential component in improving the productivity and profit of UK construction, and increasing the likelihood of the industry being able to make a positive contribution to society as a whole over the coming years. Government can help to facilitate this, but it is the industry that needs to own it, participate at appropriate levels, and pay its share of the cost.

DTI will be in the lead in taking forward new arrangements for procuring R&D in support of its role as sponsor. This will need to be put in the context of overall government policy aims for construction, and DTI's own overriding strategy for increasing productivity in the economy as a whole.

Summary of key issues:
R&D in support of sponsorship

PLANNING

- Industry to set the forward research agenda in partnership with government. A road map for research needed to tackle the most important issues. Ensure that this fits into an overall strategic policy framework for construction competitiveness and innovation
- Set targets with measurable outcomes
- For research aimed a driving innovation, ensure real championship of the research and innovation within the industry, and a real willingness to engage – if it is not there, don't fund.
- Advisory and best practice work should make better use of DTI's generic business support mechanisms adapted where necessary for construction, and of national and regional intermediaries and networks, in order to target audiences more explicitly and gain buy in from those in the wider industry that are willing to engage, learn, and move forward
- Much more emphasis needs to be placed on dissemination of outputs and sharing of knowledge, which should be planned for throughout projects. If researchers are incapable of promoting their own work, intermediaries and other specialist routes should be used instead
- Excellence from abroad should be planned for, perhaps by incorporating overseas partnerships. There is scope for international co-funding of networks and for pump priming funding to build consortia
- Research management contractors to help government define programmes of work, and projects within them, to ensure synergy and cross fertilisation

PROCUREMENT

- Procurement of work needs to offer sufficient critical mass to allow researchers to plan longer term for facilities and manpower, so should offer a programme of work rather than individual project by project funding. But arrangements should be flexible enough to allow one-off pieces of work to address adventitious and tactical issues, or to encourage particularly innovative thinking.
- A model of procurement that encourages better coupling between universities, IROs, intermediaries and industry should be developed
- The research base needs to provide industry and government with the right mix of skills, which may require far more networking than previously. In particular it will be important to ensure that the social science dimension is integrated properly into construction thinking.
- Award of work needs to be on the basis of competition. Industry should contribute at least half of the cost of research in support of its own competitiveness agenda
- Competition should be maintained – complementary streams of work would strengthen overall quality.

MONITORING

- Quality control and ongoing impact assessment will be required – regular review needs to be built in, including more interaction between researchers working on complementary issues
- Management should be rigorous, advised by an expert steering group
- New ways of ensuring quality and relevance should be developed, perhaps using independent 'external auditors' drawn from the industry.

EVALUATION

- There should be a concerted emphasis on evaluation of programmes of work, including real world impact studies.

9 GOVERNMENT AS CLIENT

It has already been stated that the largest single beneficiary of a radically improved construction industry would be the public sector – the potential savings are significant. Current arrangements do not sufficiently acknowledge that this is the case. The DTI/DTLR and Research Council programmes have tackled the generic competitiveness and regulation agendas. Public sector clients have tended to focus their own research efforts narrowly in support of their own operational needs. But with notable exceptions such as the Ministry of Defence's sponsorship of the 'Building Down Barriers' project, they have tended not to engage with the wider construction research agenda, which aims for comprehensive improvement across the industry.

For these improvements to be achieved government clients need themselves to become actively engaged in research collaboration so as to embed learning and innovation within their organisations. This implies a more substantial engagement and expenditure on generic construction research than hitherto.

Future arrangements should encourage better horizontal mechanisms to ensure that public sector clients are able to benefit fully from the opportunities to learn from and participate in construction related research. DTI has an opportunity to facilitate innovation, perhaps by working with government clients to identify opportunities where they, as clients,can take a lead in developing or demonstrating new generic process improvement and sustainability techniques and technologies.

New forms of public sector contracting, such as the private finance initiative (PFI), are already changing the climate within which decisions about procurement are made and managed, encouraging a longer term perspective which takes into account the whole life of a built asset. There is evidence that the public sector is realising better value for money as a result. Participating companies should also be able to become more profitable. This provides an opportunity for companies to invest some of this additional profit margin in R&D and longer term thinking.

Summary of key issues:
R&D in support of government as client

PLANNING

- government clients to help identify priorities
- government to define need for particular programmes of work, in consultation with expert help from government clients and the industry
- outputs targeted at public sector clients, but where appropriate utilised for wider client benefit – both working with the best clients to move the agenda forward, and providing targeted advice and support to less experienced and occasional public sector clients

PROCUREMENT

- Procurement should be done in partnership between DTI and the Office of Government Commerce, bringing in public sector clients as collaborators (and, where appropriate as co-funders) on particular projects

MONITORING

- Management should be rigorous, advised by an expert steering group including government client representatives

EVALUATION

- Evaluation should be undertaken regularly, taking into account the needs of public sector clients and quantifying the benefit of engagement in research projects

PART 2: GOVERNMENT'S ROLE IN SUPPORTING CONSTRUCTION R&D

10 GOVERNMENT AS POLICY MAKER

It is clear from earlier sections of this report that the construction industry has a major part to play in improving the wider built environment and all stakeholders' experience of it. Research will be required to support wider government policies and policy customers (for example housing, planning, environment), where the construction industry plays a supporting rather than starring role.

There is a significant amount of coordination required to ensure that the work undertaken in the construction research programme complements and builds upon work underway in other government research programmes. There are already good examples of how this might work, set out below. In each case there has been a conscious decision by funders to pool resource or expertise in order to gain added benefit from research that has relevance across funding boundaries. It would be advantageous to identify further cross cutting work, which could be jointly commissioned, and perhaps managed as a joint programme with some shared funding. This will be more important in the future, with further fragmentation of the funding streams because of recent machinery of government changes :

- DTI and DTLR have funded a study to produce guidance on methods of construction and building maintenance to increase a property's resistance to the effects of flooding. Funding also came from the Scottish Executive, the National Assembly for Wales, the Environment Agency, House Builders Federation, National House Building Council and the Association of British Insurers.
  Non-financial contributions were also made by three research organisations: BRE, CIRIA and HR Wallingford.

- Principal responsibility for promoting energy efficiency lies with the Department for Environment, Food and Rural Affairs (DEFRA). The Carbon Trust has been set up to promote low carbon technologies. DTLR has responsibility for Part L of the Building Regulations which is concerned with conservation of energy. And DTI has responsibility both for renewable energy and for construction sponsorship. All these separate responsibilities give rise to requirements for research. Departments have agreed arrangements to ensure sensible coordination, with the Carbon Trust taking the lead.
- In another example, the Health and Safety Executive (HSE) and DTI are co-funding a priority area for collaborative research scheme on 'designing for safe construction' under Partners in Innovation 2001.

Many Government policy issues have a construction dimension. A better acknowledgement of this is needed. DTI should actively promote sensible and tailored arrangements where appropriate, building on existing initiatives and consciously aiming for collaboration. Other Departments should be made aware of the opportunities for policy makers to get the best possible value and insight from construction R&D work in its widest sense.

11 CONCLUSIONS AND RECOMMENDATIONS

11.1 Investment

Tony Blair, in his foreword to the report 'Better Public Buildings', stresses the need for the UK to raise its game in the provision of public buildings and infrastructure. Delivery of the Government's huge programme of infrastructure investment requires an effective construction industry delivering good value for money. This represents an enormous opportunity for the UK construction sector. It is in government's interest both as client and as guardian of the wider public interest to encourage and help the construction industry to improve. The Review has concluded that government as a whole has not taken enough account of this in determining support for construction research in the past.

Public investment in construction research seems to be inadequate when compared to the size and importance of the sector and its contribution to the UK's economic, social and environmental wellbeing. There is no reason to think that construction is any different to manufacturing industry when considering the potential benefit from better use of R&D. There is clear and well documented evidence of the huge scope for improvement in the way the industry organises its processes and serves its customers. The public sector spends about £25bn every year on procurement from the construction industry. A relatively small upfront investment in well targeted research should yield very substantial benefit to the public purse.

There is also a need for the industry and its stakeholders to look ahead, with a more strategic vision for the future. If the industry is to play its part in securing a sustainable built environment that improves the quality of life in the UK, it needs to be profitable and innovative. The aim is for a 'virtuous circle' beginning with more and better focused R&D investment, allowing more innovation, leading to better profitability, and providing the additional capacity to invest in more R&D. The industry needs help to undertake the more strategic thinking required if is this is to happen, and government should facilitate it and join in as the major client of the industry.

RECOMMENDATION

The Review concludes that government as a whole should reconsider its level of investment in R&D to support improvement in the construction industry. It concludes that the available resources for construction R&D are the minimum that the sector deserves, bearing in mind its size and importance. It recommends that government should refocus existing resources towards more, better targeted and better utilised work on improving the productivity of the industry and improving clientship (with particular focus on gaining better value for money for the public purse), and on strategic longer term issues.

11.2 Strategic Vision

Construction has a key role to play in society in providing a better built environment. However, construction is not perceived as socially important. It is perceived as dirty, dangerous and old fashioned. If it is to address the skills crisis and attract young people it needs to be seen as central to a better quality of life for everyone, and concerned with a sustainable future. It needs to develop its vision, get widespread buy in and communicate it to all stakeholders. The research agenda needs to support this vision, and government should facilitate it as part of its sponsorship role.

Several elements must be in place to satisfy the strategic needs of government and the industry. There should be a reassessment of construction's place in the wider quality of life agenda, and agreement between key stakeholders about the contribution it can make to improving the built environment for everyone. The industry itself needs to develop a strategic vision to match this aspiration, which would have to be driven from the top. Such a vision must not be sterile, monolithic, or inward looking – it would probably involve an ongoing process of strategic thinking that would tackle key issues in a systematic and comprehensive manner. And in order to deliver this vision for the future, priorities for R&D would need to be clearly articulated, and where appropriate earmarked for government support.

The Review concludes that long term research planning should be derived from a strategic framework of the issues facing the construction industry. The emphasis should be on key competitiveness and productivity issues and their relationship to achieving sustainability. Such plans should address the well documented barriers to longer term health of the industry and its research base, and facilitate more coordinated action to overcome them.

In addition, the new vision for construction and its contribution to the wider quality of life must be publicised and debated beyond the traditional construction research base. Ideas from other industries and from overseas must be drawn in and applied to UK situations.

RECOMMENDATION

The Review concludes that several steps are needed before the construction industry can play its full part in a more sustainable future. It recommends that government should help facilitate longer term strategic thinking by:

- Facilitating a mission statement to be agreed between influential agencies about construction's contribution to the wider world and the quality of life agenda.
- Helping industry to create a strategic vision for itself, with government contributing as guardian of the public interest and major client of the industry. The strategy would provide a framework for future planning and investment in education and skills, in capital infrastructure and in R&D.
- Providing pump priming funding to facilitate industry setting a prioritised agenda for the R&D needed to achieve industry's strategic aims.

11.3 Mechanisms for change

The 3-pronged arrangement already described – 'mission statement', 'industry strategy', and 'R&D priorities' – is a straightforward concept. But making it work will need intellectual focus, enthusiasm and commitment from the construction community. Input to this review suggests that these will not be lacking.

The Review concludes that the Strategic Forum should have a pivotal role in setting industry strategic vision and key issues needing action. This would be an ongoing, constantly developing activity. The Strategic Forum will need help and intellectual input from those best placed in the industry and research community to provide rigour and analysis of strategic problems and potential solutions.

The Review therefore also concludes that a dynamic organisation is needed to provide the engine room of strategic thinking for the industry, the intellectual input required by the Strategic Forum, and a hub for prioritising R&D. This organisation would need to develop and maintain a high profile within the industry and beyond, to engage stakeholders in debate about future priorities and to raise the profile of the contribution the industry can make to creating a better and more sustainable built environment. It would require a genuine mandate from the industry in order to set priorities for government and industry research programmes.

The organisation would need several full time, well resourced individuals with the capacity to inject greater urgency, wider perspective, and more comprehensive consideration into the industry's strategic and R&D thinking. Some pump priming resource for this could be provided by government, but it would need to be funded by the industry itself within 5 years, probably on a subscription basis.

The Review concludes that CRISP as currently constituted is not geared up to perform the new, strategic thinking role now envisaged, although it could provide a nucleus for such an organisation, particularly for R&D thinking. The way in which the new organisation should be established and resourced is a matter for the Strategic Forum to consider in collaboration with Government.

The new organisation should find a way to get the best from the many expert stakeholders who are far sighted, enthusiastic and knowledgeable about the issues, and feed their views into the whole. This could involve invoking formal relationships between industry networks and clubs, with the latter feeding in recommendations and ideas for areas where they have particular expertise. Government could help industry networks and clubs to play a more concerted part in defining and acting upon the elements of the research agenda which they think are particularly important, and to which they are prepared to commit significant resources of their own.

RECOMMENDATION

The Review recommends the following mechanisms for change:

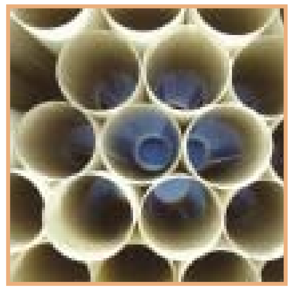
- The Strategic Forum should take the lead in engaging with key leaders in the industry and the built environment, to agree a mission statement for construction's place in the wider quality of life agenda and ensure that it is driven through the industry from the top down. Government should help to facilitate and publicise this.
- The Strategic Forum should take the pivotal role in setting industry strategic vision and key issues needing action. This would be an ongoing, constantly developing activity. The Forum will need to be able to commission work in support of this role. It seems likely that a dedicated R&D organisation would be required – building on the foundations laid by CRISP.
- The Strategic Forum needs to consider what arrangements should be established and how they will be resourced, including the role the new CRISP should play, in order to:
  - provide intellectual rigour to underpin and develop strategic thinking.
  - provide the focal point for reviewing and planning of strategic R&D priorities.
  - provide coordination to ensure that the work of other stakeholders (including networks and clubs) is properly taken into account and feeds into the overall strategy and R&D priority setting.
  - obtain a mandate from the industry for R&D priorities – the review suggests that the Strategic Forum should be asked formally to agree to an Annual R&D Plan submitted to it by the new CRISP.
  - ensure that R&D issues are widely publicised throughout the industry, by stimulating debate in the construction press, engaging in conference, seminar and network discussion, and seeking views from across the industry and beyond.

  - facilitate a major conference to raise the profile of the strategic agenda for construction, to include participation from key stakeholders from the UK and overseas.
  - commission detailed and scoping studies of important topics, which should be widely and imaginatively publicised.
  - recommend prioritisation of government's collaborative funding for programmes to improve industry competitiveness, productivity and sustainability.
  - consider establishment of a group of industry and research staff who will undertake work on strategic and research issues, and distill knowledge and views from experts within the industry and its client base, which would inform and support the work of the Strategic Forum, and help them to stimulate debate more widely.

11.4 Commissioning research

The Review concludes that the government could gain more impact from its research funding if it commissioned work under longer term programmes reflecting critical issues, identified using a robust strategic planning framework. This would ensure that longer term issues were not sidelined by the perceived potential for short term gain – programmes would need to incorporate both 'quick wins' and a longer term perspective. Work should only be commissioned on a project by project basis where unanticipated problems had emerged or if the work was by nature adventitious.

The Review concludes that such programmes should involve industry, academics and intermediate organisations and encourage collaboration and networking. Work should be procured on merit – Government should not create monopoly providers of research. Programmes of research should be managed in a way which ensures high quality work of direct relevance to industry. They should be



subject to regular audit by outside teams of independent experts. Government should be much more ready to terminate research which is not progressing satisfactorily.

The Review concludes that there should be much greater effort on follow through and take up of R&D, with robust requirements built into the programmes. There should be better measurement of the extent to which research funded by government is taken up and utilised by the industry.

RECOMMENDATION

On commissioning of research, the Review recommends the following broad approach (but see also recommendations below tied more firmly to specific government roles):

- government should commission longer term programmes of work, on merit, avoiding creating monopoly suppliers.
- programmes must encourage collaboration and networking, and ensure direct relevance to industry needs – where possible industry leadership should be secured.
- government should ensure ongoing quality and relevance by instituting peer review and audit by independent experts, as well as robust management of programmes.
- government should demand more evidence of take up and championship of research as it is underway, and put more resource into disseminating outputs, evaluating impact, and assessing return on government investment.
- government should ensure that research undertaken takes account of, and taps into, relevant international expertise.
- Government should be much more ready to terminate research which is not progressing satisfactorily.

11.5 Government focus

As noted earlier, it has been important to understand the various motivations for government intervention in construction, and support for construction research. All stakeholders need to understand government's role, and rationale for funding. It is clear that government, as guardian of the public interest and major client of the industry, has an interest in funding research:

- as **'regulator'** to provide scientific underpinning to the building regulations;
- as **'sponsor'** to increase productivity of the industry by supporting innovation and competitiveness, and encourage strategic thinking;
- as **'client'** to achieve best value for the public purse, and
- as **'policy maker'**, where improvements in construction contribute to the wider policy agenda.

11.5.1 Regulator

For regulation, the review concludes that government should fully fund long term programmes of work to support the building regulations, which should be determined by government in consultation with BRAC, BRRAG and other stakeholders.

RECOMMENDATION

It recommends that the blueprint provided in this report forms the basis of the R&D procurement strategy, taking into account the summary of key issues set out on page 20 relating to the procurement of research in support of government's role as regulator

11.5.2 Sponsor

The Review has concluded that government's current support for other construction research is in some cases spread too thinly. It needs to be refocused to where the potential for real world impact and added value is greatest, placing emphasis on embedding innovation and lessons learned into the way companies work.

The Review has concluded that there is willingness on all sides to contribute to improved arrangements to the way research in support of the construction industry is handled. And also that the industry should take greater responsibility for defining and funding the research needed to support its future competitiveness, including making better use of the infrastructure of its Professional Institutions. Government should target collaborative funding programmes carefully and selectively at the key competitiveness issues including longer term strategic development. These will be identified as part of the process of strategic thinking. Outside these areas Government should progressively withdraw funding support, leaving shorter term knowledge transfer and research on incremental improvements to be funded by the industry.

RECOMMENDATION

The Review recommends that government's role in relation to its responsibilities as sponsor should:

- help to facilitate the industry's own research agenda by supporting the new arrangements for R&D priority setting described above, which would focus on longer term and strategic research priorities related to sustainability, competitiveness, productivity, and value to clients.
- provide pump priming funding to help other research clubs and networks provide better focus for nearer market, incremental research.
- challenge the Professional Institutions to institute arrangements for collaborative consideration of key near market competitiveness issues such as setting of industry standards.
- target collaborative funding programmes at the key competitiveness issues including longer term strategic development (as identified via the new arrangements for strategic thinking), with greater involvement of government clients in industry research aimed at improving client and supply side performance.
- progressively withdraw funding support from areas that do not support strategically focused competitiveness issues and longer term strategic development.
- take account of the summary of key issues set out on page 25 of this report specifically relating to procurement of research in support of government's role as sponsor.

11.5.3 Client

The Review concludes that the benefits of construction research should be more widely recognised across Government, and that public sector clients have a lot to gain from engaging more proactively with the DTI's generic construction research programme.

Government clients have a responsibility to reflect the needs of their end users. They have responsibility for a large variety of public buildings and infrastructure – for example schools and colleges, hospitals and health centres, military installations, prisons, courts, roads, plus less specialised buildings such as offices and accommodation. Underlying R&D to optimise the performance of these buildings and how they should be procured and managed is a matter for individual government clients.

But there are wider gains to be made. DTI should work with the Office of Government Commerce (OGC) and the Government Construction Clients Panel (GCCP) to collectively identify the major problems facing clients across the public sector. The aim would be to unlock innovation in the construction industry through more demanding and innovative clientship, focusing on generic process and product improvement issues, such as prefabrication, sustainability and good design.

One approach would be to work with selected government clients, using the DTI R&D Programme to lever in extra resource where they were tackling these generic issues.

Companies engaged in PFI are entering a new phase, where greater stability and a longer term perspective offers the chance for innovative practices to bring them greater profitability. This Report has already talked about the 'virtuous circle' of R&D and increasing profitability. These companies should be challenged to increase their investment in R&D, and get themselves onto the circle.

RECOMMENDATION

The Review recommends that DTI should work with OGC and the Government Construction Clients' Panel (GCCP) to look at public sector client R&D needs, with the aim of improving innovation in government clientship overall by encouraging public sector clients to support and engage in construction R&D programmes.

In particular, the Review recommends that DTI and OGC should collaborate to pilot several new projects with public sector clients – identifying particular opportunities where R&D input could help clarify client need, refine client behaviour, and increase value to the end user. DTI collaborative R&D funding and input from industry partners could act as a catalyst for innovation where the lessons learned were generic and could be disseminated more widely. Engagement with R&D is a powerful way to embed innovative behaviour into the client side, providing a strong incentive for the public sector client's involvement. Such engagement would also provide a practical demonstration of government leadership in promoting construction innovation.

Generic issues would include process and product improvement – topics such as prefabrication, sustainability and good design. One specific area to examine is the scope for prefabricated solutions, particularly where the need is for a large number of similar facilities, even though these may be for formally independent clients within a policy area.

Identification of client specific research needs should have regard to the summary of key issues set out on page 26 of this Report, relating to procurement of R&D in support of government's role as client.

11.6 Responding to unforeseen events

One of the remits of this Review was to define how Government can best ensure the necessary competences are available which may be needed to respond to an emergency. The example often quoted is that of the discovery of the thaumasite form of sulphate attack on the foundations of certain motorway overbridges. Without swift action reliant on the expertise of BRE there might have been a threat of closure to part of the country's motorway network because of the potential threat to the safety of concrete bridges. It is impossible to anticipate what the next national emergency of this sort might be. For this reason government cannot keep standing research teams 'just in case'.

RECOMMENDATION

The Review therefore recommends that the government's strategy should be to procure all research on merit, looking for world class expertise across the board and collaborating closely with the best in field, so that the overall health of the research base is strong enough to enable it to react positively when particular problems arise.

11.7 Skills and recruitment of the brightest and best

The skills crisis facing construction and other parts of the engineering and manufacturing economy are well documented and are set out in some detail in the earlier sections of this report and its annexes. Procurement policies for R&D cannot solve these problems. But they should not exercerbate skills and recruitment problems in the industry and the research community, and should where possible improve the attraction of construction research to the brightest and best researchers.

The silo mentality within the industry is a key problem, exacerbated by the stance of the Professional Institutions. There is a need for more interdisciplinary working in the industry, which the Institutions could tackle by a more concerted effort to promote interdisciplinary skills through their accreditation procedures.

Construction must ensure that it has strategic, broad thinkers in its ranks for the future.

RECOMMENDATION

The Review recommends several strategies that Government should employ to help ensure high quality research:

- help to provide excitement for researchers by defining programmes of work in terms of quality of life issues and sustainability, rather than traditional rather narrow construction and engineering problems.
- demand multi disciplinary integrated teams for research programmes where appropriate, in particular ensuring the integration of the social science dimension and the exploitation of international expertise.
- encourage centres of excellence, and provide certainty of work in longer term programmes to allow research centres to plan manpower and resources.
- demand more people interchange between industry and academe, proactively managed to ensure proper incentives for secondees.
- help to facilitate the development of a high profile generalist construction qualification which will attract the best young talent interested in a career in construction. Ideally industry leaders should lobby for accreditation from all the main Professional Institutions. Enlightened universities would sponsor such a qualification, and industry would need to reward the individuals involved with a fast path career structure and enhanced salary.

11.8 Construction research base structure

The Review concludes that refocusing of priorities will mean less government demand for some of the more traditional construction research competencies. There will be some transition from the traditional areas of conventional materials research to newer fields looking at process, management and behavioural aspects. As government support becomes more focused on key competitiveness issues, traditional research organisations will need to pool resources and work more closely with one another in order to thrive financially and be able to attract the best talent. The coming together of research organisations could provide the basis for a new highly regarded centre for construction knowledge which would be able attract bright graduates as part of a recognised career step in the industry.

In the future it seems likely that more of the research that government funds will find a natural home in university departments, in collaboration with industry, because of its longer term strategic nature. Expertise from outside construction, and from overseas will also come more into play.

RECOMMENDATION

The Review recommends that Government should explore ways of encouraging a further coming together of the five construction research associations ('Co-Construct'). They might for example consider moving their operations to one single site, allowing them to pool resources and share common services. There may be other research organisations that would also welcome this approach and could join them. This would enable all of them to provide a more comprehensive service both to their members and to government.

The Review also recommends that the traditional construction research base – BRE, Co-Construct and the other smaller research associations – should further enhance their activity as intermediaries between academic research and industry. Government and industry will procure long term strategic thinking and work focused on key parts of the competitiveness agenda.

This work will be of wide interest to the industry at large, and if it is to have real impact needs to be embedded in the practices of companies across the country. Intermediaries play a crucial role in translating and helping industry to use the knowledge developed through basic and applied research. BRE and the research associations are extremely well placed to perform this "knowledge pump" role for construction.

The review recommends that this intermediary role should include, as a specific remit, a more targeted and tailored approach to providing industry practioners with the best information and guidance on international research and technological developments.

The Review recommends that government funding should aim to encourage collaboration with excellent research organisations with relevant expertise from outside construction.

11.9 Increasing the capacity of firms to innovate

Innovation is profitable change, affecting the bottom line. There are broadly three sorts of firms – those with well developed innovation capacity, those willing to engage but unsure of how to do it, and those who will never do so. Government needs strategies for each.

Government should encourage more construction companies to use the Teaching Company Scheme (TCS), which has been successful in promoting diffusion of academic learning into industry.

RECOMMENDATION

The Review recommends a mixed strategy to encourage greater capacity for take up of innovation in construction:

- help the best innovators to keep in the forefront internationally and learn from other industries and overseas, and document and demonstrate the benefits.
- help potential innovators to learn from the best in construction by providing 'how to innovate' guidance.
- encourage take up of TCS in construction.

Annex A

TERMS OF REFERENCE

BACKGROUND

The Government currently spends around £23m per year in commissioning construction-related research and supporting innovation. The aims of this expenditure are to underpin the development of regulation and ensure safety and health in buildings and to support the sustainability and competitiveness of the UK construction industry.

AIMS OF THE STUDY

Currently around half of this expenditure is with BRE – the majority in projects funded under the terms of the Framework Agreement that was put in place on privatisation in 1997. With the ending of the BRE Framework Agreement in March 2002, the DETR will no longer be obliged to offer a minimum value of work each year to BRE. This provides the opportunity to review the construction research competencies and facilities, which government needs to support, and to consider the processes by which priorities and research contracts are established.

STUDY OBJECTIVES

The objectives of this review are:

a To assess what research competencies and facilities government should help maintain in order:

- to provide scientific underpinning for the Building Regulations;
- to be able to respond quickly to urgent concerns which may arise over the safety and health implications of buildings and structures; and
- to support government policy to ensure a more competitive and sustainable UK construction industry.

Where "competence" is taken to mean understanding, knowledge and skills in relation to construction technologies, techniques and processes and their application to building components and systems.

b To review the processes by which research priorities are established and research commissioned in order to recommend effective systems for meeting future demand.

c To conduct a review of the research competencies and facilities.

d To make recommendations about the level and distribution of continuing support which Construction Directorate should provide to support key competencies nationally;

e To make such other recommendations as are relevant to the aims of this study.

REQUIREMENTS

In undertaking the review there will be a need to:

- develop a clear understanding of government requirements for research capabilities to support the development and review of regulation;
- understand the circumstances in which government may have to respond quickly to concerns about construction-related threats to the safety and health of the public or to protect the interests of the consumer;
- understand the areas in which research competence may be needed to support the overall competitiveness of UK construction both at home and overseas;
- understand where competencies are unlikely to be supported by the market and the need for government funding;
- consider what evidence exists as to whether or not these competencies need to be maintained nationally within the UK;
- consider whether there are advantages in clustering such competencies in a few centres of excellence which can develop synergies between research areas and integrated expertise in application to building systems;
- consider the timescales over which it is reasonable to plan for the maintenance of competencies;
- consult closely with BRE, CRISP, CoConstruct, CIC Research College, other construction research organisations; academic institutions, and companies who maintain relevant expertise;
- understand the approach adopted by EPSRC and other relevant research councils in support of the health of the research base in engineering and other construction-related disciplines and where they believe the competencies to lie;
- have knowledge of the experience which exists of the benefits and disbenefits of maintaining national expertise in centres of excellence.

Annex B

CONSULTEES

During the course of the study Sir John Fairclough held a series of meetings and interviews with key individuals and representatives from the industry, research community and funding organisations.

Andrew Abbott
Managing Director, Timber Research and Development Association

David Adamson
Estates Bursar, Cambridge University, CRISP 'client' champion

Stuart Alexander
Director WSP Group

Graeme Baker
Deputy Chairman, CRISP, former Chief Executive of BSRIA

Roger Blundell
Director of Engineering, Taywood Construction, CRISP Chairman, Technologies and Components

Peter Brandon
Pro-Vice Chancellor, Salford University

Peter Bransby
Chief Executive, CIRIA, CRISP Research Base champion

Tim Broyd
Director WS Atkins, Chair of Construction Associate Programme, Foresight

John Burdett
Secretary, Foundation for the Built Environment.

Rick Burgess
PRP Architects

Bob Cather
Associate Director, Arup

Phil Chatfield
Environment Agency

David Clark
Director of Research and Innovation, EPSRC

Garth Clarke
Former Chief Executive, Transport Research Laboratory

John Connaughton
Senior Partner, Davis Langdon & Everest

Phil Cornish
Scottish Executive, Former Director of BRE Scotland

Roger Courtney
Ex-Chief Executive, Building Research Establishment

John Coulton
Wates.

Alan Crane
Movement for Innovation

Andrew Davies
Associate Programme Manager, EPSRC

Richard Day
Principal Engineer, Concrete Society

Michael Dickson
Chairman, CIC, Chairman, Buro Happold

Malcolm Dodds
Director, Reading Construction Forum

Andrew Eastwell
Chief Executive, BSRIA

Sir John Egan
Chairman, Strategic Forum

Bob Emmerson
Chairman, Arup Group

John Findlay
Balfour Beatty Special Holdings Division

Roger Flanagan
University of Reading, Board Member, Skanska and Halcrow

Peter Gershon
Chief Executive, Office of Government Commerce

Sir Frank Gibb
Chair Finance and Audit Committee, Foundation For The Built Environment

David Guy
Economic and Social Research Council

Tony Hall
Timber Consultant

Richard Haryott
Director, Arup

John Hobson
Director of Construction, DTI

Richard Holti
The Open University

Rodney Howes
South Bank University, Chair CIC R&I Committee

Peter Hudson
Director, Crown House Engineering

Rod Kimber
Science and Engineering Director, Transport Research Laboratory

David King
Chief Scientific Adviser

Don Leeper
Senior Partner, Zisman Bowyer

Roger McAnoy
Head of R&D, Taylor Woodrow Construction Ltd

Ron McCaffer
Vice Chancellor, Loughborough University

Hugh McKay
Executive Chairman, Stewart Milne

Jim Meikle
Senior Partner, Davis Langdon & Everest, CRISP Support Unit.

Mike Murray
Director of Innovation & Technology, AMEC Capital Projects - Construction

Paul Newman
Timber Research and Development Association

Robin Nicholson
Edward Cullinan Architects, Chair CRISP Knowledge Task Group, M4I Board, Former Chair CIC

Neil Noble
Director of R&D, Arup

Turlogh O'Brien
Deputy Chairman, Arup, Ex-Chairman, Construction Research and Innovation Strategy Panel

Pat O'Sullivan
University College London, Chairman of BRAC

Graeme Owens
Director, Steel Construction Institute

Adam Poole
Reading Construction Forum

John Rackstraw
Managing Director, Pearce Retail

Phil Roberts
Hertsmere District Council, CRISP Chairman

Don Ross
Group Chairman, Pearce

Susan Sharland
Chief Executive, Transport Research Laboratory

Martin Shaw
Operations Director, Building Research Establishment

John Taylor
Director-General of the Research Councils

Steven Tilsley
Director, Metsec Plc

Hugh Try
Chairman, Foundation of the Built Environment, CITB, Deputy Chair Gallyod-Try Group

Graham Watts
Chief Executive, CIC

Doug Weston
Chief Executive Officer, Taylor Woodrow

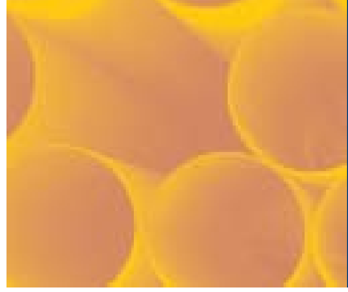
Mark Whitby
Senior Partner, Whitby Bird, President, Institute of Civil Engineers

Ivor Williams
Executive Director, European Construction Institute

Ron Williams
Director, Mott McDonald

Chris Woods
Innovation Director, RIBA, Research and Development Director, Wates Construction Ltd

Martin Wyatt
Chief Executive, Building Research Establishment



Annex C

UNDERPINNING ANALYSIS

Science and Technology Policy Research Unit (SPRU), University of Sussex
(D Gann, A Salter, J Molas-Gallart, B Cleasby, J Senker, T Sinclair & B Martin)

Part a: The review in context

Part b: Results of the review

Part c: List of tables

Part d: List of Figures

C1 INTRODUCTION AND PURPOSE

This report provides an analysis of skills and expertise in the UK construction research system, focusing on government funded R&D. It forms part of the evidence in support of the government review of construction research competencies, led by Sir John Fairclough. It provides an input to the assessment of future government funding of construction research from DTI and DTLR at the BRE and in other research institutions. The contribution of EPSRC-funded research is analysed, but recommendations for EPSRC do not fall within the remit of the review.

The study discusses the role of R&D in the construction innovation system and analyses the provision of new research skills into the sector. It describes the distribution of government research funding to different UK organisations across disciplines, drawing on a wide variety of sources some of which are new, in order to examine present and future requirements. It explores the connectivity between research organisations and potential users and beneficiaries, and assesses demands for construction research suggesting policies for government funders.

The work involved a review of existing data sources indicating the nature, size and shape of the research base. This included analysis of the flow of new people into built environment higher education courses, the quality of construction-related university departments, and previous input-output analysis of the flow of research funds in construction. It also involved developing new databases using information held by DTI (formerly DETR) and EPSRC – the principal funders of construction R&D. A small-scale survey of connectivity between industry and the research base was implemented in the UK and a survey of international experts was conducted to seek views on strengths and weaknesses of UK construction research. In addition, a workshop was held with Reading Construction Forum representing a range of industry views and in-depth interviews were carried out with senior people in construction research.

This report takes the definition of construction R&D as its starting point, based on the activities covered in the Standard Industrial Classification of construction and OECD definitions of R&D. It develops a wider concept in exploring research themes shown to be important for the future, but not adequately covered in the traditional definition.

Part a of the report sets the review in context, articulating the need for innovation in the construction sector and explaining the construction research and development system. The transition from a traditional model of construction research to encompass a broader-based set of issues is analysed. This section ends with a discussion of our approach to the study, developed specifically to engage with the particular conditions and issues found in the construction research system.

Part b presents the results of the review, describing the main research actors, sources of funding and fields of research. It provides an assessment of the extent to which current research and technical consultancy needs are being met, exploring the quality of research and its connectivity with research users. This section includes an analysis of the likely provision of new research skills. It provides a brief view of UK construction research competencies from an international perspective. The report concludes by considering future requirements and the organisation of research activities.

C2 CONSTRUCTION RESEARCH, DEVELOPMENT AND INNOVATION

C2.1 The need for innovation

Construction is a large and diverse sector of the economy, contributing 5.2% of GDP through value-added in site-based activities, and about 8% when construction-related materials and supplies are included. Its products and services provide and maintain the fixed capital – buildings and infrastructure – upon which economic and social activities rely. It is a multi-technology sector in which design, engineering and production involve the integration of materials and components produced by other industries. The project-based nature of supply and demand mean that firms often work together on specific tasks with little time or incentive to capture lessons, identify generic problems or develop general purpose technologies.

Requirements for buildings and construction-related services are changing with shifts in the economy, because of the need to meet new social demands and demographic changes and in order to reduce the long-term impact on the natural environment. New sustainability targets relating to communities and the environment are posing challenges for designers and engineers, manufacturers, constructors, technologists and researchers. Trends towards internationalisation in production, ownership and use of buildings need to be reconciled with meeting differentiated local needs and satisfying end-users. Technological opportunities need to be exploited in the context of new business processes enabling firms to improve product quality, working practices, efficiency and profitability (RAEng, 1996). This agenda has been stimulated by the Egan Report (Egan, 1998) and promoted through the Rethinking Construction organisations.

These issues shape patterns of new fixed capital investment and challenge traditional approaches to design, construction, refurbishment and maintenance. Their successful resolution in the form of new practices in engineering and business management are vital if the construction sector is to produce the types of products and services needed to support a healthy and inclusive society and a vibrant economy.

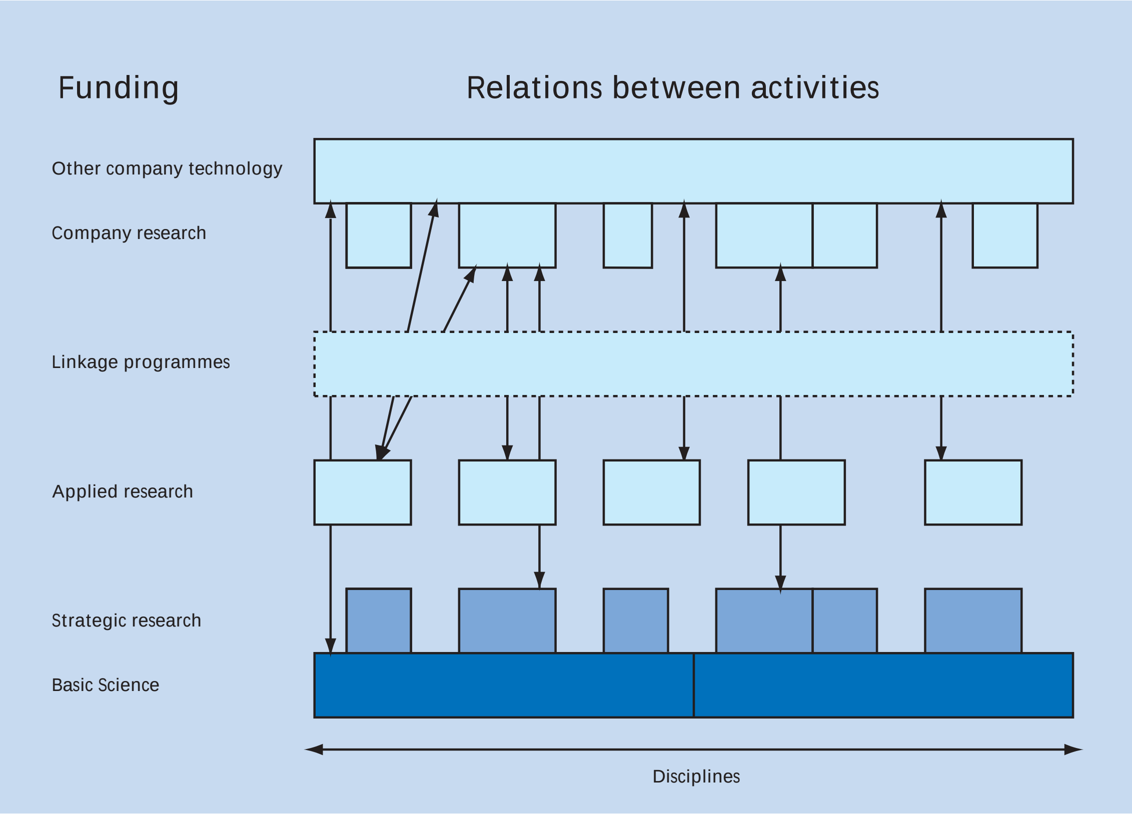
There is a political dimension to these issues during a period of widespread public concern about the quality of public spaces, places and infrastructure. Disquiet about the quality of maintenance and renewal of the railway system, our schools, hospitals and housing have kept these issues under the political spotlight. At the same time, the government has launched a number of initiatives aimed at improving investment, design, production and maintenance of buildings and infrastructure (DCMS, 2000). New procurement targets set by the OGC (Office of Government Commerce) and design guidance promoted through CABE (Commission for Architecture and the Built Environment) aim to change the rules of engagement and practices of designers and construction firms. The success of these initiatives will depend largely upon the innovative capabilities of people working in design, engineering and construction organisations, the quality and timeliness of support they receive from the construction research community and the ability of all sides to connect with the problems that need to be solved. Government funders of construction research have a central role to play in stimulating improvements through assistance with the identification of research needs and the allocation of sufficient resources to high quality research providers.

C2.2 The construction innovation system

The primary location of knowledge for innovation in the production and adaptation of buildings and structures resides within design, engineering and construction organisations and firms in supply industries engaged together in projects. Most technological choices are made by designers, engineers and project managers, by materials, component and specialist suppliers, or by well-informed clients. The majority of problems are solved by project teams, or by company technical support departments. New techniques are developed in industrial research and development departments, where new technology can be built upon existing technology. Thus in general, about 90% of innovations arise from the industrial development of pre-existing technology and not from academic science, or science carried out at arms-length in government laboratories (Langrish et al., 1972). Research and industry institutions play important support, developmental and knowledge transfer roles. They are often able to take a longer-term view and they can ask questions that might not be posed by those working in industry. The ability to think and act independently, question received wisdom and current modes of practice and to provide impartial advice to government on matters of public interest are important attributes in the research base (Gann, 1997).

The relationship between the research base and research users is one in which problems are solved and new ideas and technologies are developed through collaboration in iterative processes. The notion of a linear-model of innovation, in which scientific research generates ideas that are developed sequentially through applied engineering and technological development, resulting finally in new products and processes, is wholly inappropriate in this sector. Even in the few industries which can claim direct economic returns from basic research, the process by which this occurs is by no means linear (Rosenberg, 1991). Figure C1 illustrates the iterative linkages and relationships between basic and applied research in a mature innovation system, such as that found in construction.

Figure C1: R&D Activities in a mature innovation system



Source: (Arnold and Thuriaux, 2001)

Construction activities rely on a broad base of scientific and technological knowledge encompassing many disciplines and fields. These span knowledge about the use of space including comfort and ergonomics, properties of basic materials and composites, structural engineering, external and indoor climate, mechanical, electrical and control systems, information technology, a host of specialist engineering disciplines such as acoustics, lighting and fire engineering, production logistics and project management. Many disciplines in the natural, physical, general engineering and social sciences provide inputs of relevance to construction; including newer disciplines such as logistic systems dynamics, environmental and management sciences.

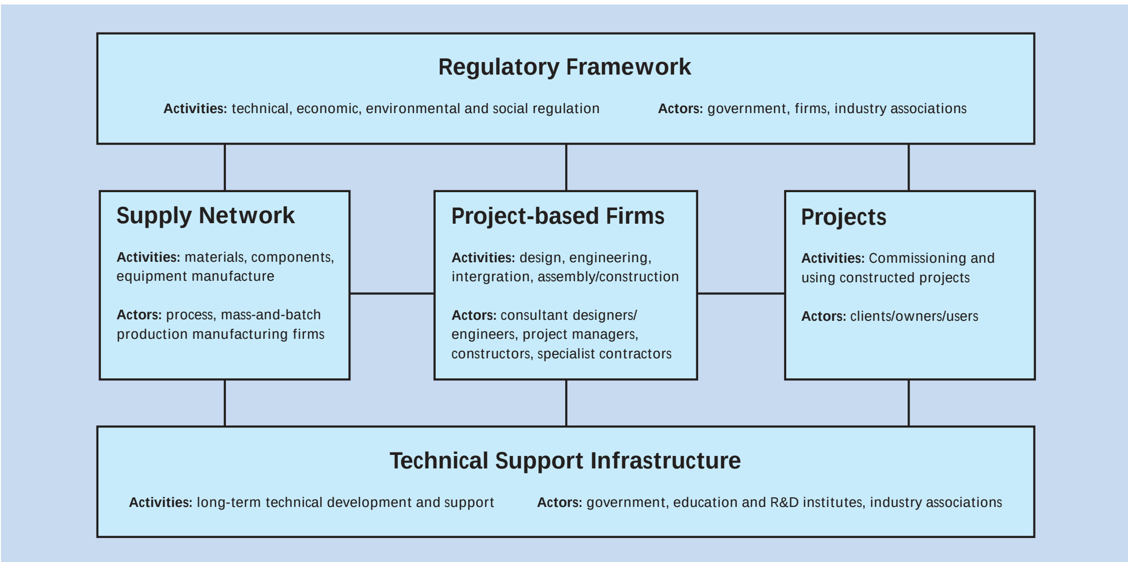
A substantial part of the research and teaching directly relevant to construction is carried out in the civil engineering, construction and architecture departments of higher education institutions. These are applied subjects that draw on inputs from other sciences, but have become recognised as disciplines in their own right, with their own professional bodies, university departments and courses, and scientific publications. In short, construction related research and higher education is carried out both within dedicated subjects that draw heavily on other academic disciplines and within other subjects and disciplines that can feed into the construction sector as well as many other economic sectors. Therefore, a disciplinary classification of construction-related sciences is not suitable as a conceptual framework on which to build an analysis of construction research capabilities and needs. Research in many areas is carried out within several disciplinary frameworks, and some disciplines encompass a very broad variety of research fields. Applied disciplines like civil engineering are in fact used as umbrella terms covering a variety of knowledge areas. An example of the wide focus of construction research is highlighted by work that is carried out on materials within civil engineering and ground engineering disciplines, as well as by materials science departments. Construction research is a multidisciplinary endeavour, which cuts across traditional industrial and institutional barriers and draws on knowledge from a wide variety of fields and technologies.

The main players in the construction research and innovation system are:

- Government funders – DTI (sponsorship), DTLR (regulations) and the EPSRC (long-range academic research)
- Independent Research Organisations (IROs) including the BRE (previously government owned);
- Universities;
- Firms, clients and users.

Figure C2 illustrates how the construction system fits together showing the main activities and actions.

Figure C2: Construction system – activities and actors



Source: (Gann, 1997)

C2.3 The role of research and development in construction

Many technical innovations in construction are stimulated by initiatives taken in the supply-chain, by demanding clients, or through changes to regulations (Gann, 2000). The nature of constructed products creates particular requirements for research, development and testing. For example, buildings are long-lived, often combining different vintages of technology, and there are many public interest and regulatory issues at stake in their design, construction and use (Nam and Tatum, 1988). These characteristics mean that there is a requirement to maintain technical knowledge in areas which in other respects may appear to be out of date. Moreover, it is not often possible to build full-scale prototypes as is the case in many manufacturing industries. Testing therefore has to be carried out on component parts or sub-elements, and there is increasing use and reliance upon simulation techniques to assess likely performance.

In broad terms, research and development is an input to the innovation process, it contributes to innovation in a number of ways (Salter et al., 2000):

- Increasing the stock of useful knowledge
- Supplying of skilled graduates
- Creating new instrumentation and methods
- Developing new networks
- Enhancing technological problem-solving capacities
- Generating new firms
- Providing social knowledge

Whilst construction is not an R&D intensive industry, R&D plays a key role in the development of the sector. From a technical point of view it is extremely important for knowledge transfer and systems integration (Iansiti, 1998). It is also important in supporting problem-solving and work-place practices, particularly when professionals and practitioners need to call upon expertise from outside their own project teams. It is likely that most smaller problems and incremental improvements are made through this type of site-based, or shop-floor model (Slaughter, 1993). To some extent, design, engineering and construction professionals already operate within a research mode, in identifying solutions to design and production issues – the 'practitioner-researcher' role (Groak and Krimgold, 1989).

On their own, narrowly focused R&D activities are unlikely to result in major benefits to project-based industries with characteristics such as those found in construction. Benefits from R&D and successful exploitation of results from particular research projects are only likely to be accrued if other parts of the innovation system are in place and operating – such as dissemination and communication, training and technical support, marketing and promotion. For these reasons, it has been shown that R&D has two faces: to develop new products and processes, and to provide the capabilities needed to absorb lessons and ideas from elsewhere (Cohen and Levinthal, 1989), (Cohen and Levinthal, 1990). The capacity to absorb new knowledge and make use of it in industry is a crucial part of the process that connects research with practice. The need to invest in these wider activities often causes confusion in terms of what is defined as R&D and what falls outside research budgets.

The nature of demand for construction research can be divided into three broad categories:

a. solving those scientific, technical, social, economic and environmental problems where there is some degree of predictability about future trends and requirements;
b. those in which there is little predictability, but where government and industry need capabilities to respond quickly to unforeseen problems or events;
c. development of new ideas and knowledge.

The efficiency and effectiveness with which research is delivered to satisfy demands in the first category depends upon strong connectivity between research sponsors, research providers and research users, together with the capability to assess future requirements. Capabilities to meet unforeseen demands in the middle category will depend upon the maintenance of a healthy, diverse and dynamic research community. One indication of this might be the extent to which the research community is capable of developing its own new and original ideas – the latter category.

Publicly funded research helps to build capabilities if it is invested in a dynamic research-base which is connected with the development of new skills – such as in university departments where teaching and research are coupled. In this context, publicly-funded academic research provides knowledge and skills on which privately funded R&D builds. Evidence from studies of links between scientific research and commercial innovation show that companies which carry out R&D cultivate strong links to national sources of academic research (Narin, 1996). They do this because universities and government laboratories have knowledge which companies find useful. This is not necessarily published information, but 'know-how' that cannot be written down (Faulkner and Senker, 1995). Much of this knowledge can only be accessed by close collaborative links over long periods of time. It often takes time for inventions to become successful commercial innovations. A healthy dynamic is therefore needed between IROs, the university sector and private firms. For example, firms tend to focus on short-term demands driven by immediate pressures of business. IROs inhabit the mid-term position, often acting as an interface between long-range research and short-term practical requirements. Problems arise when the system falls out of balance – for example if research necessary to underpin new innovation is constrained by privatisation, secrecy and short-term agendas. In this environment, researchers' skills and capabilities to conduct long-term enquiries, teaching and diffusion of knowledge can deteriorate. Eventually the research-base becomes unsustainable in terms of maintaining a long-range focus and it is difficult to renew research competencies.

C2.4 Traditional model of construction research

The traditional model of construction research from the 1920s to the 1980s was clearly divided between public and private sectors. This was the era of government support for research institutions, which were created because of their perceived importance to particular parts of the economy and to government policy-making.

The BRE was the first national building research institute of its kind. It was established to provide facilities for independent testing, monitoring and advice on building performance, regulations and production issues. The principal research user was the public sector. In the private sector, a number of leading contractors had their own technical research laboratories and were capable of developing new products, systems and processes. Until the 1980s UK construction firms tended to be more vertically integrated than they are now and this meant that research expertise could be linked up and down internal supply-chains. Few of these capabilities remain in place today and the sector invests very little in formal R&D.

In the public and independent sectors, research activities were typically segmented into several sub-sectors, each of which had a distinctive function. The three main segments were:

- universities;
- government funded laboratories;
- independent research institutes
  (often funded through subscription)

University research has typically been discipline-based, focusing mainly on long-term research issues for the advancement of knowledge and the training of new generations of researchers. Independent research organisations are usually dedicated to multi-disciplinary research focusing on a specific industry, product type or activity – e.g. timber, steel, etc. They also include independent research management and brokering organisations which liaise closely with industrial users. In the UK, such research was the responsibility of separate parts of government laboratories. For instance, technical institutes to support specific sectors of manufacturing industry carried out applied, industrially relevant research and transferred the results to industry. The activities of these different sectors of Public Sector Research (PSR) used to be complementary, with each sector drawing on the knowledge and expertise developed in the other sectors. There was a diversity of funding arrangements for PSR. Two main approaches could be identified: the Research Council model in which grants for university research were allocated on the basis of competitive peer review. These grants complemented core funding for academic salaries and research infrastructure. The second approach – the block grant system – gave researchers in relevant universities, research institutes and government laboratories a degree of freedom in deciding on the internal allocation of funds.

This traditional system has come under increasing strain – as it has in the defence industry and other areas where public sector research was once dominant. In particular the capabilities to undertake R&D have been eroded in the private sector because of the structural changes that have taken place over the past 25 years with a shift to specialist sub-contracting and a loss of in-house technical expertise. UK public research capabilities to underpin innovation in construction have been affected by underlying changes to the organisation of public sector research. A new system is emerging in which the distinctions between public and private are becoming blurred (Gibbons et al., 1994).

C2.5 Emerging patterns of construction research

The last two decades have been a period of extensive restructuring of government arrangements for PSR. Many British government laboratories and technical institutes are now in the private or independent sectors. There has been a slow but steady erosion of 'block grant' systems in favour of competitive applications for grants, leading to a marked change in the distribution of research among different sectors of PSR. A growing proportion of research grants are now allocated to specific research priorities determined by government. An increasing proportion of research now takes place in universities and there is a decreasing role for research institutes. This has led to a casualisation of scientific manpower, with a movement away from the full-time professional and experienced researchers who worked in the institutes, to part-time researchers/lecturers, staff on short-term contracts and young inexperienced research students. Government has constantly emphasised the need for all sectors of PSR to support innovation, undertake 'relevant' research and engage in technology transfer. Every sector of PSR is under increasing pressure to raise research funds from external agencies, with the result that they are all in competition for research contracts from government and industry (Senker, 2001).

The emerging model of construction research in the UK is one of a distributed network of providers in the public, independent and private sectors. These providers may be in competition or they may collaborate together – sometimes both at the same time. There has been a shift away from central government support for the BRE and it was privatised in 1997, with a five-year promissory note. The new pattern is one of public-private partnerships, loose networks, interdisciplinarity and increasing internationalisation. For example, funding from the European Union has become more important over the past 20 years and many research institutions are involved in collaborative European projects. The traditional requirements of understanding UK construction research in a national context have been superseded by the need to assess the international arena, whilst evaluating results in terms of local needs and relation to the type and size of firm and the nature of product and process.

Demands for new types of R&D are emerging, away from traditional materials focused areas towards issues of systems integration and the development of knowledge needed to work in new markets. Strains are being placed on traditional construction research processes because it is not easy for them to cope with radical changes in technologies and user requirements together with new approaches to organising construction processes within a different industrial structure from that experienced in the past. The needs to address whole-life cycle approaches, develop indicators of sustainability, manage environmental impact, integrate information systems into buildings and develop PFI proposals are all creating new demands on the research system. In some cases, new research providers are emerging to address the broader issues of innovation in the built-environment which include more customer-focused approaches, engagement with end-users and new sensitivities to construction's impact on the environment.

C3 OUR APPROACH TO THE STUDY

In order to take account of the particular nuances of construction research highlighted above, our approach to this study involved collating and analysing a number of different data sources. This included indicators of the nature, size and shape of the research base, analysis of the flow of new people into built environment higher education courses, the quality of construction-related university departments, and previous input-output analysis of the flow of research funds in construction. It also involved developing new databases using information held by DTI (formerly DETR) and EPSRC – the principal funders of construction R&D. A small-scale survey of connectivity between industry and the research base was implemented in the UK and a survey of international experts was conducted to seek views on strengths and weaknesses in UK construction research. In addition, a workshop was held with Reading Construction Forum, representing a range of industry views, and in-depth interviews were carried out with senior people in construction research.

C3.1 Defining research competencies

This study adopted a definition of construction R&D based on the Standard Industrial Classification of construction and OECD definitions of R&D (ONS, 1992). It develops a wider definition in exploring research themes shown to be important but not adequately covered in the traditional definition.

What are research competencies and how do we define these in the context of requirements in the production and use of the built environment? The standard OECD definition of Research and Development (R&D) as defined in the Frascati manual, and used in the elaboration of official R&D statistics, is not necessarily an appropriate tool for the study of innovation in the construction industries. Innovative activities that are key to the development of this sector are not formally considered R&D. Most engineering and design activities, project development and problem-solving activities are not formally considered R&D although they contribute to the innovative performance and competitiveness of the industry.

Research funding organisations and research providers have used different classifications when organising their activities into fields of enquiry. For instance, the former DETR's Business Plan approach classified projects under: best practice, construction process, safety and health, sustainable construction, and technology and performance. These formed the basis of business plans and the distribution of research funding to meet particular goals driven by government policy objectives. There is a mixture here of categories defined by research goals (sustainability, competitiveness, health and safety) with others addressing specific areas of activity (construction process). In fact, funding organisations often mix research objectives (sustainability, competitiveness) with broad disciplines (civil engineering, acoustics) and research subjects (concrete, fire protection) when defining and structuring their portfolio of activities. However, it is difficult to develop a conceptual framework to analyse and map construction research capabilities at a national level (comparing different research funders and providers) using this type of categorisation.

For a meaningful analysis of research capabilities we needed to draw on a classification of technological and scientific areas based on mutually exclusive fields. In reality, many projects are multi-disciplinary and cover more than one area of research. We devised a classification based on eight main fields where technological and organisational competencies are needed in support of the UK construction industry:

Information and communication technologies. Includes R&D on all electronics and communications to be assembled into buildings, including smart homes and intelligent building equipment.

Management processes. Including processes and techniques to manage the production and use of built environments throughout their life cycle.

Materials and components. All types of materials used in the built environment including traditional and basic materials: brick, concrete, timber, glass etc. and composites and new materials such as advanced structural materials, excluding research related to the structure of buildings.

Structures. Research related to building structures and substructures. This includes research into framing technologies, structural design and components specifically related to the structure.

Mechanical and electrical engineering. The engineering and design of electrical and mechanical systems that form part of the built environment, but excluding those related to the internal environmental control of buildings.

Internal environment. All aspects of research to assess and address the impact of buildings with respect to their internal environment, including fire safety, health and safety, regulatory issues, ergonomic design and space planning.

External environment. Techniques to assess and deal with the impact of buildings on their surrounding environment. This includes issues related to sustainability and waste management.

Other. Those projects that were impossible to classify in the above areas.

Every project was individually coded and classified according to its main purpose as stated in the project abstract. This classification provides a tool to bring analytical consistency to the study and offers a conceptual framework for the subsequent analysis of strengths and weaknesses in UK construction-related research. We have used it throughout the study, both in our questionnaires and as a means to classify the research projects funded by the EPSRC and DTI/DTLR of relevance to construction.

ANNEX C: Underpinning analysis - the review in context

C3.2 Competency mapping techniques

To review the nature of construction research competencies in the UK we used a variety of data sources. As discussed above, the efficiency and effectiveness with which research is delivered to satisfy user and societal demands depends both on the scientific and technological capabilities of the research base and on its "connectivity" with research users and beneficiaries. Our analysis identifies and develops indicators addressing both aspects: research capabilities and their connectivity. This calls for the use of a variety of indicators and research techniques in order to provide a comprehensive mapping of resources across a broad spectrum of organisations and areas of research, and of their complex interactions with users and beneficiaries.

Some of the indicators in our analysis have been used before, while others have been used in this study for the first time. Data sources used here are:

- The DTI/DTLR PACT Database – 1064 projects, every project has been coded and analysed by SPRU
- EPSRC Database – 5000 projects, of which 891 core projects have been coded and analysed by SPRU
- UCAS/HESA Database
- HEFCE RAE Database

We also obtained raw data on the most important UK government construction research support programmes. Data on all the research projects granted by the EPSRC and the DTI/DTLR PACT databases were processed into two databases that could support a detailed analysis of construction research. The information has allowed us to identify the structure of publicly-funded construction research, the main research performers (receivers of funds), their location, their main areas of activity and the partnerships established between research organisations and firms and other potential users. The analysis of subject disciplines followed the classification presented in Section C3.1 above. An additional section for projects that could not be classified into any of the categories was included.

Both the DTI/DTLR PACT and EPSRC databases were restructured to allow for consistency in analysis. The EPSRC data was classified using the following fields:

- Project name
- Contractor's name (main contractor)
- Contractor's RAE score
- Research discipline
- Total grant value
- Completion date
- Abstract

The analysis examines all projects completed after June 30th 1997. This date was chosen as the cut off point because prior to it the original data was not complete. Projects currently in progress were included in our analysis.

The DTI/DTLR PACT database included a total of 1064 research projects, with a value of just over £124million. From the database of EPSRC-funded projects we selected a total of 891 projects directly related to construction. The total value of the research projects selected was over £101million.

Gaps in this data and additional information have been captured using a range of additional techniques, most of them qualitative:

- A programme of face-to-face semi-structured interviews with key players to acquire views on existing research competencies and their relevance given future needs. The interviews were used to complete and verify our map of the construction research capabilities and elicit, explore and prioritise the most important issues concerning the future of construction research in terms of funding provision and competencies. A total of 25 interviews were carried out.
- A workshop, organised by the Reading Construction Forum to verify initial results and discuss the views of the construction industry as to existing research capacities and future needs.
- A questionnaire, distributed to 101 UK construction experts, to identify the degree of alignment between existing research capabilities as perceived by industrial players and future needs and requirements.

In addition British capabilities have been compared with those of similar countries by means of a limited international review exploring views from outside the UK on the current state of our construction research base.

C4 UK CONSTRUCTION R&D COMPETENCIES

C4.1 Sources of funding

The main UK construction-related research organisations receive most of their research funding from public sources, mainly the DTI, DTLR and the EPSRC. We have analysed all construction-related research projects funded from these sources during a four year period between July 1997 and 2001. These sources are, however, very different in their scope and objectives. The EPSRC funds research carried out at universities, often in collaboration with other government and private research centres and industry. In contrast, the DTI funds research under a variety of programmes targeted mainly at research establishments and industry, while the DTLR funds research primarily at the BRE in furtherance of the building regulations. (Data was taken from that formerly managed within the DETR Construction Research Directorate). The main funding regimes were:

- BRE Collaborative
- BRE Framework
- Competitive
- Fast track
- LINK programmes
- Partners in Innovation

The first two regimes represent exclusive agreements with the BRE, while the rest are open to a variety of organisations. Table C1 shows the distribution of DTI/DTLR construction-related research and innovation funding across these regimes. There is a clear disparity in the size of the funding regimes: three of them (Partners in Innovation and the BRE Collaborative and Framework programmes) account for 94% of the projects funded. The most important programme is the Partners in Innovation (PII) scheme, accounting for 63% of all DTI-sponsored projects and 39% of the total value of funding. In comparison, the BRE collaborative / framework regimes account for a lower number of projects (31% of the total), while accounting for 56% of the total funds invested. Therefore, BRE-specific programmes enjoy bigger project sizes. The BRE receives the largest proportion of DTI/DTLR funding, whilst delivering its research through fewer projects.

Table C1: Breakdown of DTI/DTLR Funding by Funding Regime

	Number of projects %	Monetary value %
BRE Collaborative	8.2	16.8
BRE Framework	22.8	39.2
Competitive	1.8	1.5
Fast track	1.5	0.1
LINK	1.1	0.9
LINK IDAC	0.5	0.2
LINK MCNS	0.9	0.8
Partners in Innovation	63.2	39.2
Others	0.9	1.4

Source: SPRU/DTI/DTLR PACT Database

ANNEX C: Underpinning analysis - results of the review

Table C2: Breakdown of DTI/DTLR Funding by Organisation

	Amount (£)	Funding %	Number of projects	Average size of project (£)
Building Research Establishment	79.4m	63.9	461	172k
BSRIA	5.0m	4.0	71	70k
CIRIA	4.5m	3.6	55	81k
TRADA Technology	3.5m	2.9	39	91k
HR Wallingford	2.5m	2.0	37	66k
FBE Management	1.9m	1.5	1	1.9m
Steel Construction Institute	1.9m	1.5	44	42k
BRE Scotlab	1.7m	1.3	17	98k
Others	23.8m	19.2	339	70k

Source: SPRU/DTI/DTLR PACT Database

The distribution of all DTI/DTLR funding across organisations is presented in Table C2. The data shows that, since July 1997, the BRE received over £79 million, corresponding to nearly 64% of all DTI/DTLR funding. Only 7 other organisations received funds over £1million, with the largest of these being BSRIA, with an allocation of just over £5million; and CIRIA, with funds just under £4.5million. The "Others" classification accounts for £24million (19%) of funding, distributed over 164 different organisations. In total, most of the DTI/DTLR funding (over 80%) is received by Independent Research Organisations (IROs).

The pre-eminence of the BRE among the organisations funded by the DTI/DTLR is due to the existence of the BRE Framework and Collaborative arrangements. The average size of projects at the BRE is £172,230, compared to an average per project funding of £70,584 at BSRIA; £81,514 at CIRIA and £42,543 at the Steel Construction Institute. DTI/DTLR funding at BRE appears to be for significantly larger projects than at other organisations.

The case of the FBE Management, with one single project accounting for almost £2 million, deserves special mention. This funding supports the management of the Construction Best Practice Programme (CBPP). Although FBE Management is financially independent from the BRE, it is located within the BRE campus. If funds received by BRE Scotlab were added to the total BRE funding, we could conclude that the BRE and its associated organisations receive 67.7% of total DTI/DTLR funding.

In addition to the BRE, only a small number of organisations (mainly research associations) receive substantial levels of funding from the DTI/DTLR, with nearly one fifth of the funding being distributed among a long tail of smaller research organisations. An analysis of the internal structure and challenges faced by the largest of these associations is presented in the section below.

The EPSRC awards a similar amount of funds to the DTI/DTLR in the support of construction-related research. The recipients are exclusively universities. They are not among the main recipients of DTI/DTLR funding. Therefore, the DTI/DTLR and the EPSRC distribute their funding to differentiated research constituencies. Table C3 shows the 10 academic institutions receiving the largest amount of funding from the EPSRC. The data shows that EPSRC funding is more evenly distributed between research organisations than the DTI's. This is reflected by the fact that the largest beneficiary of EPSRC funds (Imperial College) receives only 8% of total EPSRC funding of construction-related research (compared with the 64% of DTI funding absorbed by the BRE). The spread of funding is also highlighted by the fact that a total of 29 institutions received funds exceeding £1 million, compared with only 7 organisations exceeding this amount in DTI/DTLR-funded activities during the period. EPSRC funding is distributed amongst 85 of the 101 universities and there is a tail of smaller projects. DTI/DTLR funded nearly double the number of organisations, although the average project sizes are similar (£113,862 for the EPSRC and £116,727 for the DTI).

Table C3: Top 10 Institutions Receiving Funding from the EPSRC

	Amount (£)	Funding%
Imperial College	8.1m	8.0
University of Sheffield	7.4m	7.3
University of Nottingham	6.3m	6.2
Loughborough University	4.9m	4.9
University of Southampton	4.6m	4.5
University College London	4.1m	4.0
University of Salford	3.6m	3.6
University of Leeds	3.4m	3.4
Cranfield University	3.1m	3.0
Heriot-Watt University	2.9m	2.8
Others	53.1m	52.3

Source: SPRU/EPSRC Database of Construction Research

C4.2 DTI funding across research fields

The current DTI/DTLR R&D portfolio is wide ranging, including projects with the following aims:

- to establish and develop new and improved technologies and techniques, including technical support for process change and development of new and improved materials;
- to support industry codes and standards, which aim to improve competitiveness;
- to encourage business improvement, including utilisation of IT as an enabler to better performance, whole life issues, and case studies and benchmarking;
- to promote innovation and culture change;
- to support improvements in construction process, relating to product development and design, and to improve the efficiency of the process. For the former, the aims are for more satisfied clients and users, better design for sustainability and a product fit for purpose. The efficiency agenda includes improving the supply chain, promoting standardisation and pre-assembly, improving site productivity and performance, and minimising waste and pollution. Throughout, it is important to integrate thinking on human factors in the construction process;
- to underpin improved performance in respect for people issues, safety and health in and around buildings, and impacts on the wider community.

Table C4 details the distribution of DTI/DTLR funded research by research field. The figures show the dominance of four main research areas, with materials and components being the most important field both in terms of the number of projects (18% of the total) and monetary value (25% of total funds). The importance of the "internal environment" area (accounting for 20% of total funding) reflects the importance that government places upon public interest research in areas such as building regulations and health and safety. External environment also receives a similar amount of funding (19%), highlighting a commitment to research into environmental impacts and the focus on issues such as sustainability.

In contrast, our analysis shows that research into Information and Communication Technologies (ICT) and Electrical and Mechanical areas, receive comparatively little attention, both in terms of number of projects funded and their monetary value. This probably reflects the industry-wide reluctance to invest in the development of new information technologies for their application to the built environment and the development of innovative building services.

Table C4: Distribution of DTI/DTLR Funds by Research Discipline

	Amount (£)	Number of projects%	Monetary value %
ICT	4.9m	4.5	3.9
Management processes	17.1m	17.6	13.7
Materials and components	31.4m	18.2	25.2
Structures	12.1m	11.9	9.7
Electrical and mechanical	5.2m	4.2	4.1
Internal environment	24.6m	15.2	19.7
External environment	23.3m	16.4	18.7
Others	6.0m	3.2	4.8

Source: SPRU/DTI/DTLR PACT Database.

Table C5 details the distribution of EPSRC funded research across the same range of research fields. The data shows a similar selection of priority areas. Materials and components are again the most important field, concentrating an even higher proportion of the research funds distributed by the EPSRC (36%), than in the case of the DTI/DTLR. Similar to the DTI/DTLR approach, other areas receiving special attention are management processes (19%), and external environment (16%), while ICTs and electrical and mechanical receive again very little funding (only 4% and 2% respectively). The poor funding in the last two areas is again a reflection of their poor profile in the industry as a whole. The similarity between the EPSRC and DTI/DTLR distribution of funds across research areas suggests that both organisations have similar research priorities.

Table C5: Distribution of EPSRC Funds by Research Discipline

	Number of projects%	Monetary value%
ICT	3.8	5.1
Management processes	18.6	19.4
Materials and components	36.1	34.5
Structures	13.1	11.1
Electrical and mechanical	1.8	2.6
Internal environment	9.1	9.0
External environment	15.8	16.5
Others	1.7	1.8

Source: SPRU/EPSRC Database of Construction Research

C4.3 The Building Research Establishment (BRE) and the research associations

The main independent research organisations receiving funding from the DTI/DTLR are the BRE and the member-based research associations. Of these, there are five main recipients of funding: BSRIA 4%; CIRIA 4%; TRADA 3%; HR Wallingford 3%; SCI 2%. These organisations differ from one another in the nature and content of their services and they are considered in detail below. They also receive government funding from other sources, for example SCI has been sponsored by DTI's Engineering Industries Directorate and CIRIA and HR Wallingford receive research funding from DEFRA and the Environment Agency. A number of other research institutions provide research services to construction, including TRL, AEA and TWI. The level of funding as a proportion of the total DTI/DTLR expenditure is less than 1% to these organisations and we have therefore not included them in the study.

Over recent years government has supported the Co-Construct partnership: BSRIA, CIRIA, SCI, TRADA and the Concrete Society to work together in a complementary way.

C4.3.1 BRE

BRE is a centre for research and consultancy, focusing on buildings, construction and the prevention of fire. It employs a staff of 600, over 350 of whom hold professional qualifications. Their research is structured in a number of "centres of excellence" providing testing facilities for industry and government as well as engaging in R&D. The BRE is owned by the Foundation for the Built Environment, a non-profit company formed by some 150 firms, professional bodies and other organisations. The rationale is to provide a structure for BRE, allowing it to remain independent. (www.bre.co.uk)

The BRE has been in existence for more than seven decades. The organisation was privatised in 1997. The organisation differs from the sector research associations in the broader scope of its activities and for being less close to the market in some respects. BRE is also more involved in European activities and projects.

People profile

Almost half of BRE's total staff of about 600 are qualified to first degree level, with 107 Masters and 87 Doctorates. Also about half the members of staff have additional professional qualifications and 66 hold academic posts as visiting staff or in an examining or advisory roles. This linkage with academia is extended to the hosting of students to carry out work in the establishment; these students provide a good source of future employees. BRE tends to recruit experienced graduates and give them further training where appropriate. Turnover of staff is generally low, although it is higher among employees in their mid-20s. BRE receives some secondees and is involved in personnel exchanges with UK and international organisations.

Research and funding

BRE activities attempt to cover all aspects of relevance to the built environment, its components and materials, and standards and certification work. It claims to be the UK's leading centre of expertise on buildings, construction, energy, environment, fire and risk, and provides research, consultancy and information services world wide. The range of its activities is wide; Construction is one of 5 Divisions: Construction, Fire & Risk Sciences, Environment, Energy and Information. For instance, within BRE's Construction Division there are Centres for Ground Engineering & Remediation, Concrete Construction, Timber Technology/Construction, Whole Life Construction & Conservation and Structural Engineering. Its work is often interdisciplinary; over 80% of BRE projects involve two or more centres working on different aspects of the problems.

BRE is engaged in about 400 projects for public bodies (DTI/DTLR, EPSRC, EA, MOD) plus a large number of private sector projects. Although the main research activities are on the built environment, other areas of research include aviation, fire, transport, security and infrastructure.

By virtue of its size and coverage, BRE sees itself as the leading centre of expertise in the UK and as one of the top three construction-related research organisations in the world (with VTT – Finland, and TNO – The Netherlands). BRE's facilities are extensive and in many areas unique, including large-scale wind tunnels, presses, fire hall, acoustic and lighting laboratories, test houses, etc.

BRE is very active in the publication front, including the production of hundreds of academic papers each year. In contrast, however, BRE holds only 2 or 3 patents (this is somewhat surprising given the potential to develop new products and in comparison with some IROs in other fields, such as TWI – The Welding Institute).

Dissemination is also carried out through seminars, workshops and conferences in the UK and overseas. BRE-managed initiatives like the Construction Best Practice Programme and assistance in the Movement for Innovation provide a channel for dissemination through the activities or regional clubs and networks. BRE has an impact assessment unit that measures dissemination performance in specific areas.

Funding profile

BRE turnover in 2000 was £35m with an operating profit of about £2m. Most of the income is from research projects, with consultancy, training courses and sales of publications making up the bulk of the remainder. All profits are reinvested in research, mostly at BRE and in the support of PhD studentships in the built environment area.

The major change 5 years ago was the privatisation of BRE under a Framework Agreement and a steady decrease in public funding from about £19m in 1996 to about £8m in 2001. A large component of this funding comes from the DTLR and in the form of research in support of the building regulations.

For the future, BRE aims to increase its knowledge base through carrying out research rather than consultancy. Yet, BRE executives consider that any possible changes in policies supporting research for the building regulations and a decrease in DTI/DTLR funding to about £6m would constitute a worst case scenario that would drive BRE to doing less research and more consultancy.

Organisational linkages

BRE works and competes with other UK research and consultancy organisations according to particular circumstances. These circumstances are changing; for instance, although traditionally universities have not been seen as competitors, BRE executives consider that competition with higher education institutions is increasing. The main universities considered to be closer to a BRE range of activities and interests are Edinburgh, Ulster, Imperial College, Loughborough and Reading. With some of these universities, the BRE has established formal Memoranda of Understanding to frame collaborative initiatives. Closer cooperation with universities is seen by BRE executives as a way to reduce costs by making better use of BRE's unique facilities and avoiding duplication.

Strengths and weaknesses

In our interviews, BRE executives saw its strengths as the interdisciplinary nature of its approach to problems, its independent nature (unlike the member-based research associations) and its location. The diversity of BRE activities, with the associated managerial difficulties is seen as one of its weaknesses, as well as its limited engagement with industry. There was a recognition that perhaps BRE was "too academic" in its activities and approach and had to become more "applied" in outlook. The organisation's high overheads were also thought to be a disadvantage when tendering for research, particularly when bidding against universities.

In summary, since privatisation in 1997, the BRE has received 64% of former DETR construction R&D funding, amounting to about £80m. It received further funds from other government sources. Internal government evaluation processes found BRE's performance to be average in quality, albeit with some notable exceptions. But given that BRE received 64% of the funds and dominates the statistics, performance might be expected to be around average.

C4.3.2 TRADA (The Timber Research and Development Association)

TRADA specialises in the use of timber and wood products in the construction and building industries. The organisation offers quality assurance schemes through BM TRADA.

TRADA's precursor was founded in 1934. Conflicts between its status as a research association and trading company rules led to the formation of TRADA Technology Ltd, a company within the TTL Chiltern Group. TRADA Technology has a 5 year contract (from 1999) to provide the Group with research and technology services. It promotes itself as the leading timber research, consultancy and information provider for the construction industry. (www.trada.co.uk)

People profile

TRADA Technology currently has 48 people on site, 34 of whom are technical staff. Most of the staff are in the 25-40 age range, with the technical staff tending to be the younger. A majority of the technical staff are graduates, with about 10 Masters and 6 PhDs. One member of staff is a Visiting Fellow. The staff includes chartered engineers, architects and qualified wood scientists. The company runs a series of in-house, half-day training seminars each month, which technical staff are expected to attend.

TRADA is currently under-resourced, with vacancies unfilled for engineers, technicians and consultants. Particularly, TRADA finds it difficult to attract experienced personnel. Staff turnover is thought to be lower than in industry, with average length of employment in the organisation probably above 5 years.

Research and dissemination activities

TRADA policy is that technical staff undertake research as one of a number of wider tasks; in particular direct contact with sponsors is given a high priority. TRADA also organises a series of about 20 seminars to promote timber to UK professionals and runs the secretariat for some BSI standard committees.

TRADA is organised into four main groups – timber housing, engineering timber and components, non-structural uses and the timber supply chain. Research in timber housing is considered particularly important, with joint research initiatives with the BRE and an experimental full-scale six storey timber building. The engineered components group is focusing on the development of cheaper, faster and better timber components: for example, testing different floor sealants. The timber supply chain area covers benchmarking, performance indicators and market surveys for the industry.

TRADA considers itself to be particularly strong in the area of timber frames, where it considers that it has more resources than the BRE. It is also prioritising work on sustainability, waste recycling and fire research. Although it is mature, the fire testing facility at TRADA is considered to be unique in the UK. Other facilities include a "Single Burning Item", a permeability box and various structural (creep and load) and laboratory testing equipment. These facilities are leased to other organisations, and TRADA also uses facilities elsewhere (e.g. in universities) when necessary. There are no plans to invest in any major new facility in the next 5 years, but some minor equipment may be acquired for tests on slippery floorings, abrasion of floor seals, and building "airtightness".

TRADA publishes a series of information brochures (now up to about 85), target market surveys and more technical reports. About 10 papers are published in refereed journals each year, but very little patenting is done, partly because of the effort required. Dissemination is aimed mainly at members and deals with specific issues of interest to the industry.

With a strong market interface, TRADA believes it is able to assess the quality of its work from the reactions of its customers, yet it has no formal impact assessment process in place. TRADA sometimes finds it difficult to demonstrate direct results from research projects funded by DTI/DTLR, with many of the research outputs being incremental contributions, whose impact is difficult to isolate.

Funding profile

TRADA Technology traded at a loss of about £43,000 in 2000, due to a drop in subscriptions and higher site maintenance costs. Most of the company's income is from membership fees and consultancy work. TRADA has a significant number of members and clients in other sectors (like furniture and DIY) and overseas (about 10% of the total client base of more than 1000).

Research income from public sources is almost wholly from DTI/DTLR and the EU, with a single DTI/DTLR grant representing 17% of total income (down from 24% five years ago). It is expected that the share of government research income will continue to decline. At present, under the terms of this grant, the DTI provides matching funds for a number of TRADA research projects. If the grant were withdrawn, there would be a reduction in the amount of research done by TRADA, with a greater focus on short-term research projects funded by specific industry sponsors. Although there is not likely to be a timber programme in the next European Commission Framework Programme (unlike the current FP5), TRADA expects to be able to submit proposals under other programme areas.

Organisational linkages

TRADA executives mentioned "Co-Construct" as the major programme linking TRADA with other complementary organisations (TRADA sees the other IROs in the sector as complementary organisations, but the BRE is perceived as a major competitor especially since its privatisation). TRADA also works with professional institutions, particularly those for structural and civil engineers.

TRADA has regular contacts with about 15 UK universities and works most closely with Bath, Bangor, Buckingham, Aberdeen and South Bank.

Opportunities and threats

Particularly since its privatisation the BRE is seen as a competitor and TRADA compares its capacities with those of the BRE on an area-by-area basis. For instance, TRADA considers that there is direct competition with the BRE in preservatives, that TRADA is stronger in timber frames and sees the BRE as better in timber drying and sawing.

Organisations from overseas, particularly from Sweden, France, Denmark and Finland are seen as strong international competitors, all of them benefiting from higher levels of public funding.

TRADA does not expect to remain in its present form. In particular, contacts and co-operation with other European countries are likely to increase.

C4.3.3 CIRIA (Construction Industry Research and Information Association)

A research and consultancy based organisation aiming to improve industrial performance. CIRIA runs a collaborative research programme addressing different aspects of business practice including legislation and regulation, training, management and economics, sustainability and the environment. CIRIA encourages the diffusion and application of best practice through a number of networks it manages; mainly the Construction Industry Environmental Forum (CIEF) and the Construction Productivity Network (CPN). It also provides training events, in-house consultancy and supply chain seminars. (www.ciria.org.uk)

CIRIA is a not-for-profit organisation set up in 1960 as CERA (it became CIRIA in 1964), to promote R&D in construction. Its mission is to promote and disseminate best practice in the construction industry.

People profile

About 70% of CIRIA's staff are over 30, with the same percentage being applicable to engineers and to other scientific and non-technical staff. Thirty-one members of staff have a first degree, 13 of them Masters and 4 Doctorates. CIRIA is also encountering increasing difficulty in filling vacancies. Similar to other organisations, staff turnover is low with only about 15% of staff leaving within 5 years of commencing work at the organisation.

CIRIA organises internal training programmes and appraisals, with external training where this is appropriate. A number of graduates acquire more relevant professional qualifications during their time in CIRIA. Short-term employment, exchanges or secondments are limited.

Research profile

CIRIA seeks to produce best practice guidance for the whole of the construction and engineering area. Rather than being a research organisation, CIRIA works on the dissemination and application of innovative ideas over a wide spectrum of areas and produces training material. It does not hold patents nor does it engage in academic research. CIRIA executives see the organisation as one of the most respected brands in the UK construction sector, certainly on a par with BRE. In an assessment of customer services carried out by AEA Technology, CIRIA was ranked 1st or 2nd in relevant areas, beaten only by the Environment Agency and DETR. CIRIA has no research equipment facilities.

CIRIA focuses on national work, but engages in world-wide dissemination. Publications take the form of research reports (about 40 per annum) and funders' reports (about 100 per annum). CIRIA does not publish in academic journals, although reports are peer reviewed internally. Copies of all reports are given to all members and are made more widely known through the website, catalogues and press releases.

CIRIA runs learning networks (about 40 per annum), conferences and workshops (20 per annum) and holds launches of major new publications. Impact assessment is informal and is usually based on feedback from members.

Funding profile

Funding comes from member subscriptions (approximately 25%), sales (25%) and research and consultancy projects (50%). CIRIA's client base is 95% British. About half the contributions are from the public sector and the other half from private sources. DTI funding in particular is seen as strategic in nature, providing a catalyst for the development of new research activities.

This composition of research income has remained by and large stable over the past 5 years. However, in the latest financial year it has suffered significant financial losses after turnover fell to £3.5m. This is forcing the organisation to take a more commercial outlook while retaining its collaborative ethos.

Organisational linkages

CIRIA has a number of "core members" and a broader network of 500 subscribers. It sees its core members as its main partners. There is a diversified membership base including industry, construction contractors, utilities, government departments and agencies and other institutions. There are also collaborative links established with the other construction-related research associations through the "Co-Construct" initiative and one-to-one collaborative agreements with other organisations, including the BRE. There are also research links on a project-by-project basis with universities including South Bank, Imperial, Cambridge and Reading. CIRIA sees BRE, the universities and some institutions as their main competitors.

Strengths and weaknesses

CIRIA executives see independence as one of its main strengths, together with the quality of its outputs, which are often used as de facto standards. CIRIA also receives substantial industrial support and has close contacts with industry (an area in which its strongest competitor, BRE, is perceived as being weak). Yet, CIRIA is also experiencing skill shortages (especially engineers). Although the core activities are much the same as 5 years ago, dissemination and demonstration projects have become more important and it is expected that in the near future the importance of networking and support services for company applications will become more important.

C4.3.4 BSRIA (Building Services Research and Information Association)

An organisation with specific technical expertise in heating ventilation, air conditioning, plumbing, energy conservation, building and energy management systems, data communication and market analysis. BSRIA is a member-based organisation providing research services and an interface between industry and government. The Construction Directorate at the DTI is their single largest contributor to funding, but it has a wide membership including consulting engineers, contractors, manufacturers, building operators, government bodies and utilities. It currently works with over 200 partners. BSRIA's current research programme comprises forty projects valued at over £6million.
(www.bsria.co.uk)

BSRIA was formed in the late 1940s, originally as a heating and ventilating research association with 40 founder members to whom it provided information services. The association has evolved, first becoming more project-oriented, and since 1989 becoming more entrepreneurial in its outlook and organisation. At present, it has a membership of about 750, with a trading subsidiary (BSRIA Ltd) carrying out most of the research and business activities.

People profile

BSRIA has a staff of 120, most of whom are full-time. Seventy-five percent of all employees are over 32. About 66% of the staff are university graduates and more than 20% hold postgraduate qualifications. To face the skill shortage problems, the organisation tends to employ undergraduate students. In addition, BSRIA encourages its staff to engage in further education and supports them by paying fees. It is also involved in the Teaching Company Scheme and receives secondments from overseas members.

Research and dissemination profile

Research is only part (and not the most important) of BSRIA's business. A Centre for Operations Research was set up in 2001 and there are about 47 current research projects covering the environment, technology and engineering, building maintenance and operation, process and productivity and best practice and management. BSRIA has a range of state-of-the-art facilities, including heat transfer and radio test facilities, all of them run on a commercial basis.

Priorities are driven by the availability of funds, with a discernible shift away from "hard" technology (hardware, controls) to more human-centred projects (management, process). Over the last 5 years projects have also become more applied, less risky and shorter-term. There is a trend toward further commercialisation of BSRIA's activities, which is likely to continue over the near future.

A main conduit for the dissemination of BSRIA's activities is its publications, mainly application guides based on the results of its research. It also publishes market intelligence reports and presentations made at internal and external conferences and seminars. Some products (software, blueprints) have been licensed and provide some income as fees. BSRIA does not publish in academic journals.

Funding profile

Turnover in the last financial year was down to £5.4m of which 11% came from members, 22% from collaborative research, 24% from instrument solutions, 30% from contract services and information and 13% from worldwide market intelligence. Income from public sources was less than 20%, at £1.1m last year, and only 46% of this came from government departments. There is a downward trend in the income received from public sources which is expected to continue over the near future. BSRIA executives expect that the weight of research within the organisation's activities will fall even further, with projects becoming smaller and oriented to the solution of specific problems.

Organisational linkages

BRE was BSRIA's closest partner until the former was privatised. Now BSRIA perceives BRE as its largest competitor, with substantial overlapping of capabilities in some areas. The main partners are now considered to be the BSRIA members who fund research. There are 750 members, of which about 60 are actively participating in BSRIA activities. BSRIA has also developed linkages with several universities including Loughborough, Cranfield, Lancaster, Reading and South Bank. Because at times BSRIA competes with universities for work, the establishment of long-term collaborative relationships is difficult.

BSRIA has extensive international links, especially with France but also Denmark, Holland, Italy, Spain, USA, Australia and New Zealand. Germany is seen as the main overseas competitor.

Strengths and weaknesses

BSRIA executives see its independence from the trading association as an important asset, together with the enduring commitment to research, although the organisation is weak in academic research. It also has a good dissemination system, with an active distribution of its publications both at home and abroad.

C4.3.5 SCI (Steel Construction Institute)

The SCI works internationally with 600 industrial members to develop and promote the use of steel in construction. SCI was founded in 1986 with British Steel funding, following a decision to create an institute modelled after TWI. SCI has continued to expand and it is today the largest institute of its kind in the world.
(www.steel-sci.org)

People profile

SCI has 64 employees, 36 of whom are technical staff, all with university qualifications. Technical staff are also relatively young, half of them being in their 30s. Staff are reviewed annually and developed through training if new skills are required; typically each employee is allowed 5 days per year for training. The institute has several visitors from overseas (Russia, Austria, Spain) and it occasionally receives students.

Research and dissemination profile

SCI focuses on steel technology and covers areas such as product development, structural design, construction best practice and sustainable construction. SCI has no research facilities of its own, and subcontracts works to industry (mainly Corus), universities and the BRE. Its work is applied and has recently produced 3 patents.

SCI produces regular publications for its members and it participates in conferences and seminars, mainly for members (about 15 per annum), and presentations are made at conferences.

Funding profile

SCI turnover for 2001 was down to £4.2m, generating £44,000 in profits. Only 11% of its income is from the UK government. Even if this stream of funding falls further, SCI executives consider that such reduction would be

Table C6 summarises key financial data for the main IROs.

compensated by growth in other sources of income like membership subscriptions and publications. SCI also undertakes substantial assignments overseas: about 20% of SCI's work is carried in the rest of Europe, Russia, India, Malaysia, and Brazil.

Relationships profile

SCI collaborates closely with industry (Corus) and other associations in the UK and abroad. SCI has worked successfully with universities (mainly Oxford Brooks, Surrey and Imperial), although the applied approach of SCI activities is not always well suited for collaboration with academic organisations.

The relationship with BRE has proved problematic. SCI finds itself competing with the steel section at BRE, and finds that BRE practices do not seem to seek complementarity with existing resources.

Table C6 Key financial data for the BRE and Research Associations

	BRE	BSRIA	CIRIA	SCI	TRADA
Latest turnover	£35m	£5.4m	£3.5m	£4.2	£0.73m
Latest profit (loss)	£2m	£166k	(significant loss)	£44k	(£43k)
Public funding	£21.5m* (about 65%)	£1.1m (46% from central government)	£400k (50% public funds for projects)	£800k (50% DTI/ DTLR, EU).	£0.25m from DTI/ DTLR & EU
Change in public income over last 5 years	Reduced from about 90% of income in 1996	£1.3m in 1996	Little change expected	About the same	DTI/DTLR income down from 24 to 17%
Change in public income over next 5 years	Funding from a Wider range of public bodies, increasing private income	Downward trend expected to continue	Little change expected	Expect about the same	DTI/DTLR income to reduce further, continuing EU funding
Impact of reduction/loss of DTI funding	Reduction in amount of research and increase in consultancy	Reduced research activity, smaller projects, fewer in process & environment, loss of intellectual base	Loss would be catastrophic, PII is a major scheme	Not fatal, replaced by other funding streams e.g. subscriptions, marketing	Reduced research with focus on short-term, industry funded projects

Source: Interview dat

C4.4 Quality of research

As part of their internal auditing process, the DTI and DTLR attempt to measure the quality of the portfolio of research projects. This process only began recently, but a total of 276 recent projects have already been audited for their quality. This represents 26% of the total number of DTI research projects analysed in this study and as such provides a limited view of the quality of DTI funded research. The project audits were carried out internally at the DTI, with projects being evaluated on a 20 point scale (20 being the maximum score attainable). Table C7 shows the average DTI internal evaluation scores for the 6 organisations receiving the largest proportion of DTI/DTLR funds. The figures show that the average scores for the organisations are similar, with CIRIA performing best, a score of 12.2, and BSRIA performing worst with an average score of 10.6. However the variance of the BSRIA scores of 24.3, suggest that although the organisation has a low average it has a more variable project performance compared to the other lower-ranked organisation (TRADA Technology with a variance of only 4.9).

Table C7: DTI/DTLR Internal Evaluation Scores for Major Research Organisations

	Average Score	Standard Deviation	Number of projects evaluated
Building Research Establishment	12.0	2.9	112
BSRIA	10.6	4.9	21
CIRIA	12.2	3.0	20
HR Wallingford	11.5	3.8	15
Steel Construction Institute	11.8	2.9	20
TRADA Technology Ltd	10.8	2.2	18
Total Projects	11.8	3.3	276

Source: DTI/DTLR Internal Evaluation Scores & PACT Database

An idea of the quality of university research can be provided through analysis of the Research Assessment Exercise (RAE). This exercise assesses the quality of specific university departments. The last RAE exercise took place in 2001 (results available from: www.hefce.ac.uk), however these results were not available in time for analysis in this review and we have therefore used those from 1996.

RAE data for specific departments was aggregated to provide a single score for the Universities receiving EPSRC funding. The aggregate RAE score for each university was made up of the specific department scores from the civil engineering and built environment RAE fields. The RAE scores are made on a seven point scale, with seven being the maximum score. Table C8 shows the top 10 performing universities in the 1996 RAE. It shows that the level of funding received by the top 10 organisations varies greatly, with Imperial College receiving over £8m in EPSRC funding, compared with University of Wales, Swansea, which is ranked in joint first place in the RAE, but received under £1million in EPSRC funding during the four year period.

Table C8: Top 10 Performers in the 1996 RAE for civil engineering and built environment and their EPSRC Funding Levels

	RAE average score	Amount (£)
University of Oxford	7.0	1.8m
University of Wales Swansea	7.0	987k
University of Salford	6.9	3.6m
Imperial College	6.9	8.1m
University of Reading	6.8	2.5m
University of Newcastle upon Tyne	6.7	2.0m
University of Cambridge	6.6	2.5m
University College London	6.0	4.1m
University of Bristol	6.0	2.7m
University of Bradford	6.0	1.3m

Source: SPRU/EPSRC Database of Construction Research

Table C9 shows the RAE data from a different angle by examining the RAE scores for the top 10 institutions in terms of EPSRC funding. The table shows that the top 10 universities have RAE scores ranging from 6.9 (Imperial College, University of Salford) to 3.8 (University of Leeds). The low score for Leeds University suggests that there may not be a direct link between EPSRC funding levels and RAE scores – or that there were anomalies in the ways in which different departments entered their submissions to the exercise. This is further highlighted by the fact that only two of the top 10 funded universities find themselves among the top 10 Universities by RAE scores (Table C8).

Table C9: Top 10 Institutions by Revenue from the EPSRC and their RAE Scores

	RAE score	Amount (£)
Imperial College	6.9	8.1m
University of Sheffield	5.3	7.4m
University of Nottingham	5.6	6.3m
Loughborough University	5.9	4.9m
University of Southampton	5.0	4.6m
University College London	6.0	4.1m
University of Salford	6.9	3.7m
University of Leeds	3.8	3.4m
Cranfield University	5.5	100k
Heriot-Watt University	5.5	2.9m
Others	N/A	53.1m

Source: SPRU/EPSRC Database of Construction Research

C4.5 Connectivity with research users

An indicator of the connectivity between academic research establishments and other research organisations and industrial actors can be found in the structure of the projects funded by the EPSRC. The EPSRC data on the research projects it funds includes project-by-project information on the collaborative links between the universities receiving the funds and their collaborators in industry and elsewhere. These collaborative relationships provide an indicator of connectivity between the university-based research system and non-academic users and practitioners.

The number of construction-related EPSRC projects for which adequate data on industrial and government collaborators exists is 572 (in the 1997 – 2001 period). In these projects a total of 82 academic research institutions collaborate with 1019 industrial and government collaborators. Table C10 shows the main collaborators and indicates that an engineering firm, Arup, is the most active industrial partner in EPSRC funded construction research (65 projects). The BRE follows with 39 projects. Although it is the largest receiver of DTI/DTLR funds, the BRE has a relatively lighter involvement with the research capabilities residing at universities. The most active collaborators are construction engineering companies, with some participation from government agencies.

Table C10: Top 10 Industrial Collaborators with the EPSRC

	Number of EPSRC Projects
OVE Arup Partnership	65
Building Research Establishment	39
WS Atkins	33
AMEC	30
DETR (e.g. LINK)	28
Taylor Woodrow Construction	24
Environment Agency	23
HR Wallingford	23
CORUS	22
Mott Macdonald	17

Source: SPRU/EPSRC Database of Construction Research

From the point of view of the academic institutions, the breadth of their networks (Table C11) appears related to the levels of funding. In general, the major universities in terms of the volume of funds received from the EPSRC are also the ones that have established more links with non-academic collaborators. Although the average number of collaborators varies across universities, the requirement to have non-academic partners in the research projects leads to a broad relationship between successful universities and those that have established the most collaborative links.

Table C11: Top 10 EPSRC Collaborating Academic Institutions

	Number of collaborating links with non-academic organisations	Number of projects	Average number of collaborators per project
Loughborough University	187	37	5.1
Imperial College of Science, Tech & Med	147	43	3.4
University of Nottingham	131	41	3.2
University of Sheffield	112	41	2.7
University of Leeds	108	19	5.7
University of Salford	93	20	4.7
University of Cambridge	91	23	4.0
Cranfield University	83	18	4.6
Heriot-Watt University	78	15	5.2
University College London	77	15	5.1

Source: SPRU/EPSRC Database of Construction Research

C4.6 Survey of industrial connectivity

The survey of industrial users of research was designed and developed by the SPRU research team. It attempts to elicit information from industrial representatives about different organisations involved in providing R&D services in the UK. The questionnaire was seen as a mechanism to assess the industrial connectivity to different parts of the UK research base. In order to ensure some degree of comparison, the questionnaire is based on a consistent listing of research areas as the database analysis (discussed in Section 3.1). The questionnaire was piloted on a group of members of the Reading Construction Forum.

The total sample size of the questionnaire was 101 and the questionnaire was sent by mail to all respondents with a postage-paid business reply envelope. Respondents were given the option of returning the questionnaire by post or fax and were also able to request an electronic version which could be returned by e-mail. The sample was composed of a list of names provided by the DTI and included R&D managers at many of the leading UK construction, design and engineering firms. Some members of client organisations and architectural departments were also included in the sample population. Although not representative of the entire industry, the sample did compose many of the different active players and firms in the industry, including the largest organisations and companies with the largest R&D facilities.

Of the 101 questionnaires sent, 38 were returned completed (a response rate of 37.6%). Several questionnaires were returned unanswered since the people involved had moved on into other positions or occupations since the database of names was completed. The respondent profile matched the sample population profile. Several other respondents made written replies without completing the questionnaire.

The questionnaire focused on the importance of different areas of research for industrial organisations. Respondents were asked to assess the importance of the seven categories of research for their organisation. They were also asked to assess the importance of the five leading research organisations in the UK (BRE, CIRIA, TRADA, BSRIA, SCI), universities and private sector consultancies for meeting their research and technical consultancy needs. The list of the five main research organisations was based on an analysis of the current distribution of DTI funding under the Partners in Innovation (PII) programme. It focuses on the five largest receivers of DTI/DTLR funding from 1997 to 2001 in the PII programme.

A key question focused on the research capabilities of different research organisations in different areas of research. In particular, respondents were asked to indicate whether there were areas of strengths and areas of insufficient research capabilities for each of the different research organisations. The responses to areas of insufficient research capabilities were taken to mean that there was a need to develop greater capabilities in these areas. On the survey where there were no responses, such as neither an indication of strength nor of weakness, by industrial respondents, this was taken to mean that there was no pressing need to develop capabilities for this institution in this area.

C4.6.1 Research capabilities

Table C12 explores the areas of strength in research capabilities among UK research organisations for different research areas. The table is organised by size of organisation(s). The industrial respondents indicated that universities were strongest at research on information and communication technologies. Over 59% of respondents indicated that there are significant research capabilities in this area in universities in the UK. The second major area of university strength was structures at 55% of respondents. Less than half of respondents indicated areas of strong research capabilities in materials and components (42%), management processes (39%), external environment (29%), and internal environment (26%). Few respondents felt there was significant strength in mechanical and electrical systems (13%) inside the UK university system.

Table C12: Areas of strength in research capability in the UK research organisations (n=38)

	Universities	BRE	CIRIA	TRADA	BSRIA	SCI	Private Consultancies
Information and communication technologies	59%	5%	16%	3%	8%	3%	43%
Materials and components	42%	71%	26%	42%	26%	42%	16%
Management processes	39%	18%	42%	0%	0%	0%	29%
Structures	55%	45%	13%	34%	0%	47%	32%
Mechanical and electrical systems	13%	16%	5%	0%	55%	0%	34%
External environment	29%	47%	37%	0%	13%	0%	24%
Internal environment	26%	29%	8%	0%	18%	0%	18%

Note: Figures refer to the percentage of respondents indicating research strength on the questionnaire.

Table C13 presents the percentage of respondents who indicated that there were insufficient research capabilities in the university system. The findings here mirror the results of the previous areas of strength. The area with the highest number of respondents indicating insufficient capabilities was management processes (26%). This was followed by mechanical and electrical systems (21%).
A small percentage of respondents indicated insufficient capabilities for all other areas of research.

Table C13: Areas of insufficient research capability among UK research organisations (n=38)

	Universities	BRE	CIRIA	TRADA	BSRIA	SCI	Private Consultancies
Information and communication technologies	11%	24%	21%	13%	21%	11%	8%
Materials and components	16%	5%	11%	3%	5%	3%	21%
Management processes	26%	21%	8%	11%	13%	8%	11%
Structures	8%	8%	11%	5%	16%	0%	11%
Mechanical and electrical systems	21%	16%	11%	11%	5%	8%	13%
External environment	13%	5%	5%	8%	5%	8%	5%
Internal environment	11%	11%	13%	8%	8%	5%	16%

Note: Figures refer to the percentage of respondents indicating research weaknesses on the questionnaire.

In summary, industrial respondents indicated that universities were strong in information technology, but weak in management processes and mechanical and electrical systems. The relatively low scores for universities for management processes were somewhat surprising. It might reflect the lack of competency in construction management and other built environment related departments in management. It also might reflect the poor relationship between construction firms and traditional management schools in the UK.

The areas of research strength in the BRE, as seen by industrial respondents, were materials and components. Over 71% of respondents indicated that there was considerable research capability in the BRE in this area of the research. The second and third areas of BRE research strength were external environment (47%) and structures (45%) respectively. Few respondents indicated BRE strength in information and communication technologies (5%), mechanical and electrical systems (16%) and management processes (18%).

These findings are mirrored in Table C13. The data shows that areas of insufficient BRE strength were information and communication technologies (24%), management processes (21%), and mechanical and electrical systems (16%). Few respondents found significant weaknesses in the other areas of research in the BRE.

The results from both sets of information indicate that the BRE has a strong research capability in materials and components, external environment and structures. The BRE was seen by industrial respondents to be weak in information and communication technologies and management processes.

The main area of research capability for CIRIA was seen to be management processes (42%). This was followed by strength in external environment (29%) and materials and components (26%). Few respondents indicated CIRIA had research capability in mechanical and electrical systems, (5%), internal environment (8%), and structures (13%). The areas of insufficient research capability follow a similar pattern to the research strengths (Table 13). Again industrial respondents indicated weakness in information and communication technologies (21%). The number of firms indicating insufficient strength for all other areas of research were modest (between 13% and 5%).

Industrial respondents' views of research capabilities in CIRIA highlighted the growing competency of CIRIA in management processes. The higher number of respondents indicating the importance of CIRIA for management processes, rather than universities, indicates the CIRIA has developed an ability to work closely with industrial firms on management problems directly related to their areas of interest. However, these findings should be placed in context. Less than half of the sample indicated research capability for CIRIA in this area of research. The data may also indicate the need for an institution, such as CIRIA, to repackage and facilitate management processes inside industrial organisations, a role not currently played by UK universities. This role of bridging between practice and research on management processes highlights the unique role of institutions, such as CIRIA, in shaping and supporting the development of capabilities inside the sector.

The main areas of research capability in TRADA were materials and components (42%) and structures (34%). No industrial respondents indicated significant research capability for four of the seven research areas. This indicates that TRADA research capabilities are highly concentrated, or, at least, are seen to be so by industry. Few respondents indicated that there were areas of insufficient research capability in TRADA. The highest scoring area of insufficient capability was information and communication technologies. The relatively low scores for weaknesses indicated that many industrial respondents did not feel that TRADA needed to develop capabilities in these areas. It was taken for granted that there were few capabilities and that these capabilities need not be improved.

The results of the survey for BSRIA indicated considerable strength in mechanical and electrical systems (55%). A modest level of responses in materials and components (26%) and internal environment (18%) followed this score. No respondents indicated that BSRIA had competencies in management processes and structures. Areas of insufficient strength in BSRIA were information and communication technologies (21%) and structures (16%). The scores for other areas of research were modest (between 5% and 13%).

The competencies of the SCI were highly concentrated in foundations and structures (47%) and materials and components (42%). No other areas of research were seen to be present by industrial respondents. Areas of insufficient strength for the SCI were information and communication technologies (11%). The scores for other areas of research were low.

For private consultancies, the area of greatest research capability was information and communication technologies (43%). The next strongest areas of research were mechanical and electrical systems (34%) and structures (32%). The lowest scoring areas of research capability were materials and components (16%) and internal environment (18%). In terms of areas of insufficient research strength, materials and components received the highest score (21%). It was followed by internal environment (16%). No other areas were indicated to have insufficient research capability.

C4.6.2 Meeting research needs

Table C14 explores the importance of future areas of research for UK construction industry representatives. The highest scoring area was information and communication technologies. This research area was rated as important or very important by 78% of all respondents. The second most important area of research was management processes, with 73% of respondents indicating important or very important. Materials and components (62%), external environment (58%) and structures (50%) followed these two areas. The research area receiving the lowest number of scores was internal environment (42%), followed by mechanical and electrical systems (47%).

Table C14: Importance of future areas of research for the UK construction industry representatives (n=38)

Research areas	% of Respondents[1]	Mean	Std. Deviation
Information and communication technologies	78%	4.0	1.1
Materials and components	62%	3.8	1.1
Management processes	73%	4.1	0.9
Structures	50%	3.4	1.3
Mechanical and electrical systems	47%	3.3	1.1
External Environment	58%	3.7	1.2
Internal environment	42%	3.2	1.2

[1] Percentage of respondents indicating important (4) or very important (5) on the survey.

The standard deviation of the responses reveals that the highest level of agreement among the responses was over the importance of management processes as an area of research. The level of disagreement was greatest for the importance of structures. The standard deviations in all other research areas were similar.

In the survey of industrial connectivity, we asked respondents to indicate the general importance of external organisations in helping them to meet their organisations' research needs. The responses show that 59% of the sample thought external organisations were important or very important in meeting their research needs (Table C15).

Table C15: The importance of different organisations for meeting industrial research needs (n=38)

	% of Respondents[1]	Mean	Std. Deviation
External organisations in general	59%	3.7	1.0
Universities	42%	3.2	1.2
BRE	45%	3.1	1.2
CIRIA	59%	3.4	1.3
TRADA	14%	2.3	1.2
BSRIA	42%	2.9	1.4
Steel Construction Institute	15%	2.5	1.1
Private sector consultancies and firms	33%	2.9	1.3

[1] Percentage of respondents indicating important (4) or very important (5) on the survey.

Respondents were then asked to indicate the importance of each external research organisation in meeting their organisation's research needs. The data shows that CIRIA was the most important external research organisation in meeting the research needs of industrial respondents. The BRE was the next highest scoring external research organisation. Universities and BSRIA both scored 42% of respondents. TRADA and the SCI were indicated as important by only 14% and 15% of respondents. Private sector consultancies were seen as important by close to a third of the sample of industrial firms.

Some care is required in interpreting these figures, but they do suggest that organisations such as CIRIA and BSRIA, although small in relative terms of funding, do provide an important range of research services to the UK construction industry. The low scores for both the BRE and universities are unexpected. They could be accounted for by problems in industry-university or industry-BRE interactions.

C4.6.3 Meeting technical consultancy needs

The survey of industrial users focuses on the importance of different organisations in providing technical consultancy to industry. The survey indicates that relatively few industrial firms need external organisations in general for technical consultancy. Only 33% of the sample indicated that external organisations were important or very important to their organisation.

The most important source of technical consultancy was seen to be private sector firms and consultancies (44%). This finding is consistent with expectations, given the role of these organisations in providing these services in the market. The second most important actor in the system was seen to be CIRIA (34%), followed by BRE (31%) and BSRIA (28%). Only 19% of respondents indicated that universities were an important source of technical consultancy. The scores for TRADA and the SCI were also modest.

Table C16: The importance of external organisations in meeting industrial technical consultancy needs (n=38)

	% of Respondents[1]	Mean	Std. Deviation
External organisations in general	33%	3.3	1.0
Universities	19%	2.7	1.0
BRE	31%	2.7	1.3
CIRIA	34%	2.6	1.3
TRADA	13%	2.2	1.1
BSRIA	28%	2.7	1.3
Steel Construction Institute	16%	2.5	1.1
Private sector consultancies and firms	44%	3.4	1.0

1 Percentage of respondents indicating important (4) or very important (5) on the survey.

C4.6.4 Research collaborators

In the last question of the survey, we asked respondents to list the three main research organisations with whom their organisation collaborates. The responses indicate that the most common collaborator was CIRIA (Table C17). CIRIA was followed by the BRE. The number of universities mentioned was relatively high, but these patterns of collaborations were fairly widely dispersed across the UK university sector. No single university was cited by more than six respondents. The highest scoring university was Salford, followed by Loughborough and Southampton. There were a wide variety of other organisations cited by respondents, including HR Wallingford and the Transport Research Laboratory at Leeds University. The considerable variety in the types and names of organisations that UK industrial respondents work with indicates the need for research funding to be widely distributed across different types of research organisations operating both in the construction sector and elsewhere.

ANNEX C: Underpinning analysis - results of the review

Table C17: Research organisations listed as collaborators by industrial respondents (n=38)

Research organisations in the UK	Number of listings
CIRIA	18
BRE	16
BSRIA	7
Salford University	6
TRADA	4
Loughborough University	3
University of Southampton	3
Transport Research Laboratory	2
University of Warwick	2
University of Manchester	2
Steel Construction Institute	2
University of Reading	2
HR Wallingford	2
Advantica	1
De Montfort University	1
Cambridge University	1
University of Surrey	1
Tavistock Institute	1
Zethus Centre	1
Concrete Society	1
European Construction Institute	1
Leicester University	1
WSP Environmental	1
University of Bath	1
University College London	1
Environment Agency	1
Oxford Brookes University	1
Ceram Building Technology	1
Construct Association	1
Health and safety labs	1

Note: SPRU was mentioned by a number of respondents, but we have removed these citations from the table because of the dangers of a response bias given SPRU's role in conducting the survey.

C4.7 Higher education and skills

If UK construction research is to thrive in the long-term it will need to recruit bright, well-trained people from a wide range of disciplines into firms and research institutions. Evidence from the IROs already indicates problems in recruitment. Analysis of the numbers of people entering higher education courses in built environment disciplines provides an indication of the likelihood that these problems will worsen. In addition, some of the respondents to the survey of UK industrialists made disparaging comments about the connectivity and relevance of university research:

"Universities are generally inaccessible and unapproachable to professionals and have little hands on contact with us on projects. This must change – we need a closer ongoing working relationship between the academic research world and the practitioners on the ground. It's all a symptom of the classic British disease – research and innovation takes too long to filter through to industry, by which time Germany, the USA, have already done it."

"Architectural education within British universities is now generally very weak – it is too arty-farty/design theory led. Architects are their own worst enemies – but should be leading innovation on the ground, with help from universities."

A critical mass of qualified personnel is usually required if research is to be carried out and exploited. Most construction firms and professional engineering design organisations are very small. Many are preoccupied with day-to-day activities and survival and are therefore not motivated to engage in longer-term research activities. Though some may appreciate the desire and need to innovate, their size often makes it difficult for them to engage in longer-term, formal R&D processes in a structured way. For example, of the 160,000 contractors operating in the UK, fewer than 20,000 employ people with higher technical qualifications and only around 200 employ 5 or more people with such qualifications (Gann, 1991).

There is considerable concern that the supply of professional skills required in the production and maintenance of the built environment has not matched the changing needs of the construction industries (Andrews and Derbyshire, 1993). A report commissioned by the Ove Arup Foundation in 1998 showed that there had been a steep decline in the number of students applying to join courses related to the Built Environment (Gann and Salter, 1999).

The report also showed that new types of skills were being required to tackle issues related, for instance, to environmental protection and working on contaminated land – Table C18.

Despite efforts to analyse and cope with these problems, it is arguable that the failure in the supply of skills to match emerging demands in the sector has become worse during the 1990s.

Table C18: New skills and competencies

New specialist skills	New general and integrative competencies
Brief development and definition	Environmental planning
Design management	Transport planning
Production planning, assembly	Space planning, syntax and changing working patterns
and installation management	Business Analysis
Specialist project finance	Dynamics and complex systems analysis
Specialist legal advice	Building economics and life cycle analysis
Risk assessment and management	Team building, co-locating, concurrent engineering
Safety management	Partnering and supply-chain management
Supply-chain management	Interdisciplinary skills to integrate engineering and social science expertise
Procurement and logistics	Understanding users and regulatory frameworks
Instrumentation and control systems	Delivery of integrated products and services
Non-destructive testing	
Facilities management	
Energy management	
Water management	
Building physics	
Materials science	
Contaminated land engineering	
Geotechnical engineering	
Structural engineering	
Façade engineering and design	
Mechanical and electrical engineering	
Heating, ventilation and air-conditioning	
Manufacturing engineering	
Wind, seismic and vibration engineering	
Fire engineering	
Lighting design	
Acoustical engineering	
Simulation and modelling	
Computational fluid dynamics	
IT systems and data management	
Documentation control	
Machinery operation and maintenance Environmental planning	

Source: (Gann and Salter, 2000)

ANNEX C: Underpinning analysis - results of the review

Beyond the total employment figures, it is useful to understand changes in the number of students entering and leaving UK universities for careers in the industry. Numbers of students are likely to have a profound impact on future research capabilities through two main mechanisms:

- The training of skilled problem solvers has been shown to be the main mechanism for transferring research into practice, and therefore, the most important link between publicly funded research and industrial practice (Salter and Martin, 2001). A fall in student numbers could indicate a decline in the benefits of publicly funded research, as the main mechanism for dissemination and application of research results weakens.
- The number of students enrolled in UK universities affects the capacity of the university sector to perform research. Research in the UK is supported both through direct research grants to individuals and groups in departments, and through core teaching funding based on a complex formula that includes the number of students enrolled in a department. A decline in student numbers can have a serious impact on the amount of research that is performed in a research area. For example, in extreme cases, it can mean the closure of whole departments and the shift of lecturers into new departments and subject areas.

It is therefore important to understand the overall situation in student numbers and to link these patterns of change to larger issues in the development of research capability for the UK construction industry. It would be helpful to have a historical record of students entering and leaving UK universities, yet it is difficult to trace the trends of student numbers because the datasets changed between 1993 and 1994. The data from polytechnics and universities in the pre-1994 period are not directly comparable to post-1994 data, when the binary divide between polytechnics and universities was ended (UCAS, 1998). However, the available data suggests that home applications for civil engineering rose between 1988 and 1993, and started to decline in the middle of the 1990s (Engineering Council, 1998). Home applications in civil engineering reached a peak of 3,265 students in 1992. It has since declined to 1820 in 1998.

Similar declining trends are reflected in more recent data from UCAS on the number of applications from 1994 to 2000. The data shows a 43% decline in applications to civil engineering courses from 1994 to 2000. This is a precipitous fall and in part reflects an overall shift in applications out of engineering disciplines to other fields of study, such as design studies and biological sciences. The decline in the number of applications for courses in building and construction (including surveying, housing studies, construction management and other courses on the built environment) was even more dramatic. From 1994 to 2000 there were 45% fewer applicants to UK courses in building and construction. The fall in applicants to Architecture degrees was less sharp but still significant: a fall of 11% between 1994 and 2000 (Table C19).

It must be noted that if the rates of decline were to continue into the future, the number of students in the built environment would rapidly collapse. By 2009 the number of applicants to civil engineering courses would have fallen to 0, while the last applicant to building and construction courses would enter university by 2012. So far, the declining trend line shows little signs of bottoming out (Table C19).

The decline in applications to courses in the built environment is reflected in the number of acceptances. In civil engineering, the number of acceptances fell by 28% from 1994 to 2002, with most of the falls taking place during the last years of the 1990s. As the number of students in civil engineering falls, several civil engineering departments are threatened with closure. The decline in building and construction students has been less dramatic, but it is still substantial at 10%. The only area bucking the trend is architecture, where there was an increase of 19% from 1994 to 2000 in the number of acceptances to UK courses. Further, these declining patterns contrast with the rise in the number of applications and acceptance at UK universities. At a time when the number of students was increasing dramatically, fewer students were engaging in courses related to the built environment. The worrisome feature for the Built Environment is that the decline in interest in construction-related courses took place simultaneously with a dramatic growth in university numbers. In 2000, the general growth in student numbers seems to have hit a plateau, with a slight levelling off in the total number of applications and acceptances in the UK university system. Whether in a period of stagnation in student numbers, construction-related courses will be able to attract more students remains an open question. Recent experiences and the poor reputation of the industry as an employer do not bode well for the capacity of these disciplines to attract growing numbers of students against a general background of stagnation or decline in the total number of applications.

Table C19: Applications in built environment courses, 1994 to 2000

	1994	1995	1996	1997	1998	1999	2000	% Change
Civil engineering	5,104	4,538	4,207	3,766	3,442	3,080	2,905	-43%
Architecture	3,269	3,237	3,097	3,179	3,004	2,797	2,900	-11%
Building and construction	4,006	3,860	3,232	2,803	2,671	2,369	2,205	-45%
Total Built Environment	12,379	11,635	10,536	9,748	9,117	8,246	8,010	-35%
Total All Subjects	405,117	419,442	418,400	458,781	446,457	442,931	442,028	9%

Source: UCAS

Table C20: Acceptances to undergraduate courses in the built environment, 1994-2000

	1994	1995	1996	1997	1998	1999	2000	% Change
Civil engineering	3,453	3,347	3,218	3,143	2,869	2,624	2,493	-28%
Architecture	1,972	2,159	2,174	2,368	2,311	2,333	2,340	19%
Building and construction	2,367	2,718	2,430	2,498	2,345	2,211	2,131	-10%
Total Built Environment	7,792	8,224	7,822	8,009	7,525	7,168	6,964	-11%
Total All Subjects	247,567	264,738	273,032	308,236	302,683	307,677	311,635	26%

Source: UCAS

With the steep decline in the number of applications, a higher proportion of applicants to courses in the Built Environment are being accepted into courses. For example, in 1994, 59% of those who applied to courses in building and construction were accepted into the course; by 2000, this figure had reached 97%, indicating that almost every student who applies is accepted. The figures for civil engineering have also changed markedly from 68% in 1994 to 86% in 2000. Even in architecture, a field with only a slight decline in applications, the rate of acceptances over applications has increased significantly from 60% to 81%.

Overall, the acceptance/applications ratio has grown for the whole of the UK system; yet, the patterns for construction-related courses are much more pronounced. While, in 1994 the ratio in the Built Environment courses was similar to the overall average (63% to 61%), in 2000 a significant difference had emerged (87% ratio of acceptance in the built environment compared with an average of 71%).

Table C21: Acceptances by application in undergraduate courses in the built environment, 1994 to 2000

	1994	1995	1996	1997	1998	1999	2000
Civil engineering	68%	74%	76%	83%	83%	85%	86%
Architecture	60%	67%	70%	74%	77%	83%	81%
Building and construction	59%	70%	75%	89%	88%	93%	97%
Total Built Environment	63%	71%	74%	82%	83%	87%	87%
Total All Subjects	61%	63%	65%	67%	68%	69%	71%
Difference between all subject and built environment	-2%	-8%	-9%	-15%	-15%	-17%	-16%

Source: UCAS

Although this data would suggest a decline in the quality of students, data on the GCSE scores of students accepted to Built Environment courses from 1994 to 2000 presents a more mixed picture (Table C22). Since 1994, the number of students accepted who achieved 21 or more GCSE course points increased from 31% to 50% of the total class. In 1994, the percentage of students with over 21 GCSE points accepted into civil engineering was slightly below the average for all subject groups (31% to 36%), but by 2000, civil engineering was above the average for all other subject groups (50% to 44%). Other indicators point in a similar direction. The percentage of students accepted with less than 10 GCSE points fell from 18% in 1994 to 8% in 2000. This percentage compares favourably to overall trends in other subject groups. In 1994, 18% of all students had less than 10 points, a percentage that felt to 13% by 2000. Similarly, the picture for architecture is also encouraging. In 1994, architecture had roughly the same number of students scoring 21 or more points on their GCSEs as all other subject groups, but by 2000 the percentage had increased to 54%, a full 10% above the national average for all other subject groups. The number of students accepted with less than 10 points has also remained low and below the average for all other subject areas. This likely increase in the quality of civil engineering students took place in the late 1990s and may reflect changes in the way engineering courses are accredited and developed. Instead, in building and construction the percentage of students with 21 or more GSCE is far below the average: only 8% in 1994, and 13% in 2000 still well below the 44% average. These figures suggest that the quality of entrants to courses in building and construction has been low in the past and has remained so over the past seven years.

Table C22: Main qualifications of home applicants accepted to engineering and built environment courses, 1994 to 2000

	1994			1996			1998			2000		
	21 and over	20 to 11	10 or fewer	21 and over	20 to 11	10 or fewer	21 and over	20 to 11	10 or fewer	21 and over	20 to 11	10 or fewer
General engineering	34%	32%	34%	40%	31%	29%	43%	30%	27%	41%	35%	24%
Civil engineering	31%	51%	18%	37%	50%	13%	44%	45%	12%	50%	42%	8%
Mechanical engineering	36%	45%	19%	46%	41%	14%	50%	41%	10%	51%	40%	9%
Aeronautical engineering	45%	40%	15%	55%	32%	13%	59%	30%	11%	62%	29%	10%
Electronic engineering	33%	44%	22%	41%	42%	17%	41%	43%	16%	43%	43%	14%
Production and/or Manufacturing engineering	23%	51%	26%	24%	54%	23%	31%	51%	18%	34%	52%	14%
Chemical engineering	44%	44%	12%	56%	34%	10%	57%	33%	9%	61%	33%	6%
Architecture	37%	51%	12%	46%	43%	11%	49%	42%	9%	54%	37%	9%
Building/ Construction	8%	51%	42%	12%	53%	35%	11%	55%	34%	13%	55%	31%
Total subject groups	36%	46%	18%	36%	46%	18%	32%	48%	20%	44%	43%	13%

Source: UCAS

To sum up, the number of students in construction-related disciplines is declining, although students entering courses in civil engineering and architecture exhibit high standards of educational performance. This suggests that the overall decline in student numbers has not yet influenced the quality of the student intake in civil engineering and architecture. In fact, the overall decline in the number of students in civil engineering may have led to the closure of poorly performing departments, thus helping explain the relatively high scores of the remaining applicants.

The intake of foreign students has helped to dampen the impact of the decline in UK-based applications to Built Environment education courses, especially in civil engineering. From 1994 to 2000, the percentage of foreign students in the UK Built Environment student population has increased significantly. In 1994, foreign students represented 17% of the total number of applications, by 2000 the percentage had increased to 23%. The area of largest growth in foreign student numbers took place in civil engineering, where the share of foreign students rose from 20% to 35% from 1994 to 2000.

Table C23: Percentage of overseas students as a share of total students applying to built environment courses, 1994 to 2000

	1994	1995	1996	1997	1998	1999	2000
Civil engineering	23%	29%	34%	39%	37%	35%	35%
Architecture	23%	31%	34%	36%	34%	31%	27%
Building and construction	11%	15%	18%	17%	14%	14%	12%
Total Built Environment	19%	25%	29%	32%	29%	27%	26%
Total All Subjects	10%	12%	13%	13%	13%	12%	12%

Source: UCAS

Table C24: Percentage of overseas students as a share of total students accepted into built environment courses, 1994 to 2000

	1994	1995	1996	1997	1998	1999	2000
Civil engineering	20%	27%	33%	39%	37%	36%	35%
Architecture	19%	25%	28%	30%	30%	27%	23%
Building and construction	10%	14%	14%	13%	11%	11%	10%
Total Built Environment	17%	22%	26%	28%	27%	25%	23%
Total All Subjects	8%	9%	10%	10%	10%	10%	10%

Source: UCAS

The number of women applications and acceptances in Built Environment courses remains well below the averages for all other subject groups. Women represented only 10% of the applications to civil engineering courses and 8% in building and construction – the level of acceptances is naturally higher at 15%. The number of women applicants to architecture is somewhat higher at 24% in 2000, unchanged since 1994. Overall, the percentage of women has remained stable or fallen, signalling that the number of women students has fallen in line with the reductions in male students. It is clear that greater efforts will be required to attract women into courses in the Built Environment.Source: UCAS

Table C25: Percentage of women applicants to built environment courses, 1994 to 2000

	1994	1995	1996	1997	1998	1999	2000
Civil engineering	12%	13%	14%	14%	15%	8%	10%
Architecture	24%	28%	30%	32%	35%	20%	24%
Building and construction	9%	11%	11%	11%	12%	9%	8%
Total Built Environment	14%	16%	17%	19%	21%	12%	14%
Total All Subjects	50%	51%	51%	52%	52%	47%	47%

Source: UCAS

Table C26: Percentage of women in acceptances to built environment courses, 1994 to 2000

	1994	1995	1996	1997	1998	1999	2000
Civil engineering	13%	15%	15%	16%	15%	15%	15%
Architecture	27%	30%	30%	34%	37%	37%	36%
Building and construction	11%	12%	12%	13%	14%	14%	14%
Total Built Environment	16%	18%	18%	21%	21%	22%	22%
Total All Subjects	50%	51%	52%	52%	53%	54%	52%

Source: UCAS

Given these patterns of applications and acceptances, the decline in total enrolment in UK courses in civil engineering and building and construction is hardly surprising. The exception is in architecture, where the number of students enrolled has increased since 1996. The fall in enrolment is particularly sharp in undergraduate full-time building and construction students (a 28% decline between 1996/97 and 1999/00) and civil engineering (a 21% decline during the same period). Part-time postgraduate courses are the only group where the number of students in building and construction has grown, showing that many of the programmes offered at the postgraduate level have been successful in reaching out to practitioners.

Table C27: Number of students enrolled in higher education in the UK

	1996/97	1997/98	1998/99	1999/00	% Change
Civil engineering	18,272	17,319	16,167	15,100	-17%
Architecture	12,800	13,406	13,656	13,300	4%
Building and construction	20,097	18,696	17,985	17,160	-15%
Biological sciences	81,750	87,987	89,338	90,740	11%
Design studies	40,672	42,819	44,535	44,390	9%
Engineering (no civil)	115,769	113,607	112,546	108,810	-6%
All Subjects	1,756,179	1,800,064	1,845,757	1,856,330	6%

Source: HESA at www.hesa.ac.uk

C5 INTERNATIONAL COMPARISON

This section reviews the results of a small-scale survey of international construction experts to identify UK strengths and weaknesses in construction research, changes over time, and the implications for future government support of construction research.

A questionnaire survey instrument was used to obtain the perspectives of international experts on recent developments in UK construction research competencies. Questionnaires were e-mailed to 125 international experts chosen from membership lists of CIB (Conseil International du Bâtiment – International Council for Building), ENBRI (European Network of Building Research Institutes) and ENCORD (European Network of Construction Research and Development) and members of the international academic community selected from the editorial boards of Building Research and Information and Construction Management and Economics. Two reminders were sent to non-respondents.

There was a low response rate to the questionnaire, with only 10 returns, several of which were only partially completed. An additional 8 respondents wrote to explain they could not complete the questionnaire because they lacked sufficient knowledge.

In general, questions about UK capabilities in existing areas were better completed than those about capabilities in important emerging areas.

There was also a better response to questions about capabilities in universities than those in independent research institutes or private companies. Some respondents felt unable to make any judgement about whether British capabilities had improved or declined in specific areas during the past five years. It would appear that international experts' difficulty with completing the questionnaire arises from the fragmentation of construction research into numerous fields and sub-fields. Most experts have knowledge of the UK's construction research capabilities in their own specific field, but little knowledge of other research fields relevant to construction.

The very low response rate means that the following results should be treated with extreme caution. They provide only a rough indicator of views and attitudes. As expected from a small-scale study, little consensus emerged from the responses, except for the view that US universities had the strongest ICT and materials research capabilities. A majority of respondents also indicated that Finland had the strongest ICT research capabilities in independent research institutes.

Assessments about UK research capabilities – whether in universities, independent research institutes or private companies – were diverse. In most research areas, respondents indicated that UK research capabilities either tended towards international leadership or followed international trends. However, in every field except structures, at least one respondent judged that UK university research attained international leadership. This may be explained by the respondent who noted that:

"There are hot spots in universities in the UK, where international standing is high. However, it is too hit and miss, with under-funded facilities the legacy of political complacency. The science and engineering base within the construction sector is generally weak as a result."

Another strength of UK university research is its links with industry. In the words of two respondents:

"Looking from outside, UK research base seems to have established a very sound base of cooperation with the industry in many sectors."

"Universities do an excellent job cooperating with the private sector."

Diverse assessments were also made about research capabilities in the UK's independent research institutes and private companies. At least one respondent judged that UK independent research institutes attained international leadership in every research area except the external environment. Similarly, at least one of the assessments of private companies' research capabilities considered they were international leaders, except in the area of structures. The cluster of respondents who considered that UK ICT research attained international leadership in both independent research institutes and private companies may indicate UK research strength in this area. This view is supported by several respondents who consider UK research capabilities in ICT to have improved in the past five years. Responses also suggest that there have been significant improvements in research on the external environment, and some improvement in management processes and the internal environment. One respondent tried to give an overview of the UK's research capabilities. He said:

"It is very difficult to assess the capabilities as a whole. On average, I would state that UK construction research is very visible and active everywhere. The UK expertise seems to have a very wide market globally. However, how much that contributes to the competitiveness of the industry in the UK is totally another matter. I sense that in the UK the gap between research and successful innovation is far greater than in most developed countries, although very positive, world class examples of companies such as BAA can be found."

Another suggested that the main problem with UK research could be its fragmentation, and made a suggestion about how that could be remedied:

"There seems to be too many players competing and some form of networks (virtual centres of excellence) with more specific mandates may accelerate knowledge production and transfer to the industry. ...Again looking from outside, the role of various traditional players (professional associations), new emerging groups on regional and national level etc. are not clear. This may give comfort to many since it slows the rate of change but is also slow. More radical, focused action may be required, but is it politically do-able?"

Respondents identified a wide range of future research areas that they believed would be increasingly important in the next five years. In the following list, the areas in bold type are those where the UK is considered to have strong research capabilities – Table C28.

Table C28: Possible future research topics identified by international experts

Construction to facilitate the needs of ageing population
Smart buildings
Underground structures & infrastructure
Soil mechanics and geotechnics
Infrastructure renewal/rehabilitation
Rehabilitation of towns
Integration technology/management
Process integration using IT
IT systems (embedded systems, ubiquitous computing, e-business)
Simulation and virtual reality
Materials
Construction process re-engineering
Industry's performance improvement
General use of technology
Facilities management and facility automation
Construction in developing countries
Recyclability
Environmental and energy management
Safety (covering structural safety, safety at work, safety against crime and crime prevention etc.)

Respondents were also asked to assess whether UK research institutes were adequately equipped with up-to-date research instruments, equipment and/or facilities. Two respondents who judged they were not adequately equipped identified the new equipment required:

"Materials labs, various other labs and testing facilities."

"For structures: large-scale testing facilities and equipment.

For ICT: powerful VR technology and simulators.

For embedded technology: demonstration laboratories.

For sustainable, energy-efficient construction: demonstration laboratories.

For internal (indoor) climate: full-scale laboratories, equipped with sensors and measuring equipment."

The results of the survey suggest that UK construction research capabilities do not achieve international leadership, except for "islands of excellence". Weakness in some areas may be related to lack of investment in new facilities and equipment. There is a need for decisions to be made about where the UK wants to position itself in construction research, the areas it wants to prioritise, and those where it is acceptable for leadership to be taken by other countries. Such decisions could be guided by the views presented above about the UK's current and emerging strengths. In addition, there appears to be a need to decide whether independent research institutes and university departments should play mainly competitive or complementary roles in providing the knowledge, the trained personnel and the research infrastructure required for innovation by industry.

ANNEX C: Underpinning analysis - results of the review

C6 CONSIDERATIONS FOR THE FUTURE

This section of our report presents a number of issues for future consideration emerging from the study. We have not attempted to draw conclusions or recommendations to these – to do so would be beyond the scope of our remit and capabilities. The points identified here are raised in anticipation that they may be considered through the process of discussion and strategic development following the launch of the Fairclough Review.

C6.1 Industrial research requirements

The UK construction sector faces a multitude of challenges to improve its performance and rationalise its structure in order to increase the quality of its products and services. It faces increasing international competition and the continued threat of skills shortages, in part because it is failing to attract high calibre engineers, technologists, designers and managers. There is a real opportunity for construction to exploit and develop new technologies and processes; yet to harness them industry needs to increase its investment in skills and R&D. Success will depend upon the sector's collective capabilities to:

- Create a vision and strategy for research;
- Articulate research needs in collaboration with clients, end-users and researchers;
- Provide a stimulating work environment, attractive to new researchers;
- Encourage and promote connectivity within and between researchers in the BRE, research associations and universities;
- Promote and support exchanges of personnel between industry and the research-base;
- Engage more fully in international networks of technologists and researchers.

The innovative capacity of construction rests on the research activities and performance of a wide range of disciplines and on its ability to absorb new ideas. Our study shows that this system plays an important part in enhancing the performance of the sector. However, few areas were identified in which UK construction research is outstanding internationally – areas of strength included geotechnics. Nevertheless, many research areas were thought to be adequately covered, with mixed views on the capabilities of providers in different parts of the research-base.

C6.2 Government research requirements

Government, as a client and through its roles in developing regulations and promoting higher standards, needs to be able to call upon independent, multi-disciplinary research services. For example, the DTLR, in its role as regulator, requires independent advice from researchers who are seen to be impartial by construction stakeholders and their clients. Changes in the structure of the research base are causing some concern over the future provision of these services. Regulations have provided an important stimulus to innovation over the past 20 years, particularly in areas of environmental and social concern. In order to keep pace with wider social, economic, environmental and technical changes a critical mass of research capability needs to be maintained. Our interviews suggest that the current £6m annual expenditure on regulations is the minimum required to deliver the regulatory function. However, there is a backlog of research that needs to be completed in order to make timely changes to regulations. Government should therefore consider investing more in research in support of its regulatory function.

C6.3 Research priorities and international connectivity

The selection of priority research areas should take into account existing national strengths and weaknesses, both in the public and private sectors. Consideration should also be given to longer-term fundamental research that may be important in the future. Capabilities in selected research areas could be increased rapidly by following the example of small European countries, such as Sweden and Norway. They encourage their scientists to enter international research collaborations that provide access to the latest knowledge and techniques. Scientists and technologists who have studied and worked abroad with leading research groups also enable these countries to establish "niches of research excellence". Parts of the UK construction research base are well connected in international networks, but more could be done here, particularly in making links to disciplines outside the more traditional core areas of construction-related technology and materials research.

In addition to allocating resources to research priorities, the UK needs to maintain capabilities in all areas of construction research, so as to be in a position to understand, absorb and use the results of research carried out in the rest of the world.

Conducting research is often an entry ticket to international networks (SPRU, 1996). Thus, even modest R&D efforts can help open up access to world frontier research. The construction research community and its funders therefore need to maintain a critical mass of capable researchers to simultaneously tackle interesting new fields and respond to unforeseen problems in existing technologies, systems and processes.

C6.4 Restructuring government funding

There has been extensive restructuring of government arrangements for public sector research in the last two decades across many OECD countries. The UK has been a leader in the development of new forms of private-public research relationships. Privatisation of research organisations, including the BRE, has been part of a broader shift in the model of pubic research provision, away from reliance on centralised, stable funding of discipline-based organisations, towards project-based competitive funding, public-private partnerships, interdisciplinarity and internationalisation. In response, research organisations are taking on new roles and challenges. Recent changes in the roles of government departments with the separation of responsibilities for construction research into the DTI and DTLR is likely to increase the need for co-ordination between different research sponsorship activities. The health of the research base depends to an extent on the type of funding it receives. A balanced portfolio which re-aligns the research objectives and funds within and between the different government sponsors will be necessary.

C6.5 Effectiveness and competitiveness

The effectiveness of the emerging research system will depend on the quality of individual organisations and the strength of the links between those players – i.e. on communication, co-operation and collaboration. Competition is increasing between different types of organisations that used to collaborate in less confrontational environments. Whilst competition brings new benefits, it also results in problems such as loss of cohesion within the system. We found that industry is concerned about this shift. Traditionally some leading firms have contributed in-kind to the activities of research groups. Now, as the output of these contributions is being commercialised, industry feels that their in-kind contributions may no longer be appropriate. At the same time, the income that is derived from these commercial activities does not appear to be sufficient to cover the gap left by an apparent decline in government contributions.

The impact of short-term, competitive contracting on the development of specialised facilities and expertise, and on the long-term accumulation of knowledge needs to be questioned (Seaden, 1997). It seems unlikely that short-term contract researchers in discipline-based university departments will be able to replace the work done by multi-disciplinary teams of research staff employed in independent research institutes dedicated to construction research. Moreover, the specialised and wide ranging sources of knowledge necessary for construction research suggest that a cadre of full-time, experienced, professional researchers are required, to provide a pool of scientific expertise, to absorb knowledge from external sources and to integrate it with their existing knowledge. The fragmentation of construction research and the importance of geographic proximity for technology transfer suggests that independent research institutes should continue to play an important role in technology transfer. They could provide a valuable service to firms by acting as intermediaries between specialised university researchers and industry, identifying nearby university departments with the expertise required by firms. There is extensive evidence that geography has an important influence on patterns of innovation (Salter et al., 2000). Small firms are most likely to search for research expertise in local universities, but even large international companies rely on local competencies for their research projects. Users, especially small and medium sized firms often experience difficulties in finding specific sources of expertise in a widely dispersed university sector focusing on longer-term knowledge development. On the other hand, technical institutes are less able than university research teams to have capabilities in new technological areas and find it difficult to keep up-to-date in fast-moving fields (Mason and Wagner, 1999). The future challenge is therefore to develop a competitive environment for different types of research, problem-solving and dissemination services while maintaining a degree of collaboration between research performers and improving their linkage with industrial users.

Meeting local needs whilst maintaining a national research system capable of competing internationally could result in duplication of effort in some areas. Much of the literature on the economics of science is devoted to the 'wastefulness' of duplication (Stephan and Audretsch, 2000). But studies of past achievements show that near-duplication is not necessarily a bad thing; for example it may encourage healthy competition in getting cost-effective solutions to market, or promote better tailoring of products to precise customer needs. At best, a 'race' to develop a key application may lead one participant to make a fundamental breakthrough, as happened in the foundation of the pharmaceutical industry.

Annex D

BUILDING REGULATIONS FORWARD REQUIREMENTS

The specific issues that are expected to drive Building Regulation requirements for research competencies over the next 5 years are summarised below. The required research competencies for each Approved Document Part of the regulations have been placed in three distinct areas:

D(i): Integrity of the building
D(ii): Operational performance of the building
D(iii): Occupant interactions

They are also summarised in terms of the range of expertise and facilities that would be needed.

Table D(i): Integrity of the Building

PART A – Structure

Issues	Required Competencies Expertise	Required Competencies Facilities
Whole life performance, particularly failure mechanisms and modes, for wide range of structural materials, including timber, concrete steel and masonry. Development of BSI and CEN codes and standards relating to AD A, particularly the Basis of Design head code and sub-codes. Evaluation, up dating of data and modelling of operational and extreme loadings, particularly for imposed static, dynamic and accidental loads. Evaluation of crowd loading and structural interaction. High rise structures, particularly the integrity of the design and materials used Risk assessment procedures relating to disproportionate collapse. Impacts of climate change, particularly maintenance of data used to define characteristic wind and snow loadings. Fire resistance of building constructions using fire engineering methodology. Ground stability and foundation design, particularly on brownfield sites. Competency in the development and application of structural assessment methods particularly for novel structural components and connections.	Material science Structural engineering Construction techniques and design experience Geotechnical engineering Methods of structural analysis Test and assessment expertise Failure investigation Eurocode and BSI application and development	Load measurement (static and dynamic) Structural system analysis (modelling and full scale demonstration) Component test rigs Material chemical and microstructure analysis Numerical modelling Access to expert systems (ESDU etc)

Table D(i): Integrity of the building (cont)

PART B – Fire safety

Issues	Required Competencies Expertise	Required Competencies Facilities
Tracking and influencing the development of test methods for reaction to fire and fire resistance. Competency in the development and application of Fire Safety Engineering and computer modelling, including extended application of codes and standards. Fire investigations. Environmental impact of fire Requirements for fire protection, and detection including the development of practical solutions for reducing fire spread in buildings.	Fire safety engineering CFD and FE benchmarking Fire chemistry and toxicity Human factors Virtual reality modelling Test and assessment expertise Incident investigation ISO, CEN and BSI application and development	Resistance and Reaction to Fire test rigs, including ad-hoc testing Modelling facilities including physical scale and numerical Burn hall with environmental protection facilities

PART C – Site preparation and resistance to moisture

Issues	Required Competencies Expertise	Required Competencies Facilities
Detailing to reduce radon risks Protection from landfill gas and chemicals Climate change effects such as ground water levels, driving rain Membrane/insulation design and whole life performance Remediation of contaminated land	Contaminated land specialisms Micro structure analysis regarding contaminants and their effect on structural materials and plastic membranes Physics, specifically radon measurement and control Contamination modelling	Landfill monitoring equipment Radon monitoring equipment Numerical modelling Humidity transmission cells

Table D(ii): Operational Performance of the Building

PART D – Toxic Substance

Issues	Required Competencies Expertise	Required Competencies Facilities
Review of BSIs and possible need for changes	Internal Air Quality assessment Toxicology	In situ vapour monitoring equipment

PART E – Resistance to the passage of sound

Issues	Required Competencies Expertise	Required Competencies Facilities
Transmission of horizontal impact noise Human perceptions of noise disturbance Effect of wall linings and fixings and developments regarding absorbing/insulating materials Interaction between sound and thermal insulation Development of constructions with improved sound insulation	Building acoustics Building practice Human factors	Flanking laboratory Transmission suite Intensity measurement equipment

Table D(ii): Operational Performance of the Building (cont)

PART F1 - Ventilation

Issues	Required Competencies Expertise	Required Competencies Facilities
Development of performance based guidance to ensure IAQ requirements will be achieved Assessment of material VOC emission rates so they can be matched with ventilation rates to ensure health limits are not exceeded Development of natural ventilation systems, including ventilator location and performance Development of active ventilation control eg mechanical ventilation with heat recovery, etc Occupant influence on VOC load and emission rates Effect of attached and integral garages on IAQ Ventilation and IAQ requirements for occupant productivity particularly in workplaces and schools Monitoring and guidance on air tightness Factors effecting the incidence of air-born pathogens Design to prevent infestation, particularly for novel organic insulation materials Climate change impact on humidity, the spread of microbial growth, population of house dust mite Avoidance of Sick Building Syndrome	Chemistry Occupational health CFD modelling Human factors Building practice Ventilation Engineering Micro-biology Pathology Epidemiology Psychology	IAQ measurement equipment including tracer gas Ventilation rate measurement equipment Test houses VOC measurement

PART F2 – Condensation in Roofs

Issues	Required Competencies Expertise	Required Competencies Facilities
Control of condensation to avoid structural damage and improvement of thermal insulation Development of more energy efficient methods with particular regard to buildability Interstitial condensation prediction, measurement and avoidance	Moisture dynamics Building practice Meterorology	Test chambers Computer modelling

Table D(ii): Operational Performance of the Building (cont)

PART H – Drainage and waste disposal

Issues	Required Competencies Expertise	Required Competencies Facilities
Effects of climate change particularly drainage capacity and back flooding and rain water ingress to sewage systems Development of grey water and solid waste storage systems Effect on drainage systems of settlement on brownfield sites Reed bed waste processing Implications of developments to underpinning BS standards Interaction with the requirements of Drinking Water Directorate Regulations	Hydrodynamics and flow modelling Bio-chemistry Materials science Health sciences Geotechnics	System testing and modelling capabilities

PART J – Combustion appliances and fuel storage systems

Issues	Required Competencies Expertise	Required Competencies Facilities
Design of hearths, flues, fire places and chimneys (masonry or metal) for safety, and reliability, including the effects of material durability, failure modes, renovations, and repairs Air supply for combustion and interaction with ventilation and energy efficiency Increasing use of flue-less appliances, particularly the implications for ventilation and contaminants Safe accommodation of combustion systems, particularly the effect of workmanship in retrofitting Control systems, particularly operability and effectiveness Implications of developments to underpinning BS standards and transition to ENs	Building services Materials science CFD modelling Toxicology (CO and NO) Knowledge of domestic appliance market developments (oil, gas, solid and LPG fuels)	Flue and chimney test rigs Gas measurement equipment Appliance test rigs Chimney test house Numerical modelling

Table D(ii): Operational Performance of the Building (cont)

PART L – Conservation of fuel and power

Issues	Required Competencies Expertise	Required Competencies Facilities
Practical applications of the revisions to AD L Gaps and scope for misinterpretation of the performance requirements in AD L Implications of conservatories and extensions on whole building performance Climate change implications and application of low carbon and no carbon technologies Control of summer overheating and appropriate application of air conditioning Implications of novel heat acquisition, retention and distribution systems, eg ground heat recovery, mechanical ventilation with heat recovery, under-floor heating. Improvement of existing housing stock Making more use of daylighting and performance of lighting systems	Building and building services design Building energy modelling Practical experience regarding buildability and workmanship, commissioning, operation, and maintenance Construction type requirements Moisture control Economic and carbon assessment	Environmental Test houses Material property and durability measurement U value measurement and modelling Building modelling software

Table D(iii): Occupant interaction with the building

PART G – Hygiene		
Issues	Required Competencies Expertise	Required Competencies Facilities
Control of water storage temperature to prevent legionella Control of water delivery to prevent scalding Use of recycled water and long term hygiene control for recycled water systems	Medical sciences Occupational health and hygiene Micro-biology Building Services Human Factors	Micro-biology testing Mobile sampling and monitoring equipment

PART K – Protection from falling collision and impact		
Issues	Required Competencies Expertise	Required Competencies Facilities
Accident statistics gathering and analysis including population profile changes Human reactions under normal and emergency conditions Factors including climate effecting surface grip and safe operation. Optimum stair geometry for whole population use Accidents associated with building features including self closing doors	Human factors Statistical analysis Experimental design Building practice	Stair, ramp and barrier test rigs Load monitoring equipment Slip resistance measurement

PART M – Access and facilities for disabled people		
Issues	Required Competencies Expertise	Required Competencies Facilities
Compatibility with the Disability Discrimination Act Effects of sensory impairment on access, egress, signage, lighting, acoustic performance, and fire safety Implications of assistive technology developments Ergonomics of building services and sanitary facilities, particularly design for access Assessment of opening forces	Human factors Psychology Ergonomics and physical limitations arising from disabilities Acoustics Awareness of assistive technologies	Building feature test rigs Acoustic measurement Access to representative samples of people

Table D(iii): Occupant interaction with the building (cont)

PART N – Glazing – materials and protection		
Issues	Required Competencies Expertise	Required Competencies Facilities
Accident statistics gathering and analysis Safety of roof lights Assessment of novel glazing fixings Implications for safe access for cleaning arising from extensions including conservatories Requirements for location of safety glass Impact assessment for new glass products Adoption of CEN impact test	Human factors Building practice	Material property measurement equipment Impact test equipment

Electrical Safety		
Issues	Required Competencies Expertise	Required Competencies Facilities
Electrical building services in dwellings Underlying causes of accident statistics Monitoring the impact of changes to BS7671 (previously IEE wiring regulations for buildings) such as the new provisions for sockets in bathrooms	Electrical engineering Building services Practical knowledge of safe design and installation Survey and statistical analysis	

Telecoms (Broadband)		
Issues	Required Competencies Expertise	Required Competencies Facilities
Ensuring the building structure is not a barrier to the introduction of new telecommunications systems Tracking system developments, particularly use of radio connectivity which might obviate the need to consider building structure	Knowledge of new systems	

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Annex F

CONTACTS

THE DEPARTMENT OF TRADE AND INDUSTRY

The overall aim of the DTI's Construction Industry Directorate is to secure an efficient market in the Construction Industry, with innovative and successful UK firms that meet the needs of clients and society and are competitive at home and abroad. The DTI supports construction innovation and research to improve the UK industry's competitiveness, quality and performance, the environment and the quality of life. The Teaching Company Scheme is the Government's flagship scheme for promoting technology transfer by facilitating the establishment of project-based partnerships between the science base and companies.

Tel: 020 7215 5000
www.dti.org.uk
E-mail: construction.research@dti.gov.uk

Tel: 01367 245 200
www.tcsonline.org.uk

THE DEPARTMENT OF TRANSPORT, LOCAL GOVERNMENT AND THE REGIONS

The DTLR is responsible for health and safety issues including development of both Building and Fire regulations. This complements the existing work of the Health and Safety Commission and Executive both of whom report to DTLR ministers.

Tel: 020 7944 3000
www.dtlr.gov.uk

OFFICE OF SCIENCE AND TECHNOLOGY

The Office for Science and Technology acts to plan, develop and manage UK involvement in the European Union's science and technology activities. Proposals under the EU's sixth framework Programme on research provide significant opportunities for partnership funding for Construction related research. LINK is a collaborative R&I programme supported by government departments, Research Councils and industry.

Tel: 020 7215 6428
www.ost.gov.uk

Tel: 020 7630 0001 (LINK Co-ordinator)
www.dti.gov.uk/ost/link

OFFICE OF GOVERNMENT COMMERCE

OGC has been set up to lead a wide-ranging programme to modernise procurement in government, and deliver substantial value for money improvements. Working at the heart of government, OGC is developing an integrated procurement policy and strategy across government. OGC represents the UK on procurement matters in Europe, in the World Trade Organisation (WTO) and other international fora

Tel: 0845 000 4 999
www.ogc.gov.uk

CONSTRUCTION RESEARCH AND INNOVATION STRATEGY PANEL (CRISP)

The Construction Research and Innovation Strategy Panel operates to encourage competitiveness through the appropriate use of research and innovation and to identify and promote the construction community's research and innovation priorities to major funders. Government are represented on the Panel as are the Highways Agency, EPSRC and academe.

Tel: 020 7379 3322 (CRISP Secretariat)
www.crisp-uk.org.uk

RESEARCH COUNCILS

Both EPSRC, the Engineering and Physical Sciences Research Council, and ESRC, the Economic and Social Research Council, develop and manage research programmes relevant to the construction industry.

Tel: 01793-444100 (EPSRC)
www.epsrc.ac.uk

Tel: 01793-413000 (ESRC)
www.esrc.ac.uk

RETHINKING CONSTRUCTION

Rethinking Construction is the banner under which the construction industry, its clients and the government are working together to improve UK construction performance. Rethinking Construction partners aim to showcase innovations in both products and performance through Demonstration Projects and highlight best practice available within the industry. They also seek to encourage the industry and its clients to adopt the principles of rethinking construction to their mutual benefit.

www.rethinkingconstruction.org.uk

- **The Movement for Innovation (M4I)**

  The Movement for Innovation (M4I) aims to lead radical improvement in construction in value for money, profitability, reliability and respect for people, through demonstration and dissemination of best practice and innovation. Around 170 demonstration projects have been set up to date – each having identified a particular innovation, or a number of innovations, to improve the construction and procurement process.

  Tel: 01923 664 820 (Enquiries)
  www.m4i.org.uk

- **The Housing Forum**

  Leads on housebuilding, refurbishment and repairs and maintenance in the public and private sectors.

- **The Local Government Task Force (LGTF)**

  Leads on best practice for local government clients.

- **The Central Government Task Force (CGTF)**

  Leads on best practice for central government clients

- **Construction Best Practice Programme**

  The CBPP is funded from within the DTI's construction programme and is steered jointly by DTI and the construction industry. The CBPP has a key role in ensuring that the industry is made aware not only of the range of management best practice (innovation available and the benefits of adopting best practice) but is also given help to put it into practice.

  Tel: 0845 605 55 56 (CBPP Helpdesk)
  www.cbpp.org.uk

GLOSSARY

BERD	Business Expenditure on R&D
BRAC	The Building Regulations Advisory Committee
BRE	The Building Research Establishment
BSRIA	The Building Services Research and Information Association
CABE	The Commission for Architecture in the Built Environment
CBI	Conseil International du Baitment (International Council for Building)
CBPP	The Construction Best Practice Programme
CID	Construction Industry Directorate (of DTI)
CIC	The Construction Industry Council
CIRIA	The Construction Industry Research and Information Association
CIRM	Construction Innovation & Research Management Division (of DTI)
CRISP	The Construction Research and Innovation Strategy Panel
DCMS	Department of Culture, Media and Sport
DETR	The former Department of the Environment, Transport and the Regions.
DTI	The Department of Trade and Industry
DTLR	The Department of Transport, Local Government and the Regions
EA	Environment Agency
ECI	European Construction Institute
ENBRI	European Network of Building Research Institutes
ENCORD	European Network of Construction Research and Development
EPSRC	Engineering and Physical Sciences Research Council.
ESRC	Economic and Social Research Council
FBE	Foundation for the Built Environment
GCCP	Government Construction Clients Panel
HEFCE	Higher Education Funding Council for England
HSE	Health and Safety Executive
ICE	Institute of Civil Engineers
ICT	Information and Communication Technology
IRO	Independent Research Organisations
M4I	Movement for Innovation
MBRAs	Member Based Research Associations
OECD	Organisation for Economic Co-operation and Development
OGC	Office of Government Commerce
ONS	Office for National Statistics
PiI	Partners in Innovation
PSR	Public Sector Research
R&D	Research and Development
RAE	Research Assessment Exercise
RAs	Research Associations
RMCs	Research Management Contractors
SMEs	Small and Medium Enterprises
SPRU	The Science and Technology Policy Research Unit
SCI	Steel Construction Institute
TCS	Teaching Company Scheme
TRADA	Timber Research and Development Association
TWI	The Welding Institute
UCAS	Universities and Colleges Admissions Service

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SUBCONTRACTING AND COOPERATION NETWORK IN BUILDING CONSTRUCTION: A LITERATURE REVIEW

Julio Y. Shimizu[1] **and Francisco F. Cardoso**[2]

ABSTRACT

Owing to recent structural transformations in the construction sector in many countries like Brazil, production is much more subcontracted nowadays than in the past. Consequently, supply chain management became more important, including the management of subcontractors.

Cooperation networks appear to be an advantageous way of supply chain organization, which is beneficial to subcontractors and building firms. Cooperation networks are consequences of strategic alliances between some agents of the supply chain. Such firms, organized together, cooperate, reaching better results than they would obtain individually.

With the main focus on subcontractors and building constructors, this paper, based on a literature review, seeks to deal with the decision of make or buy (subcontracting) and to analyze its importance in the formation and development of cooperation networks in building construction. Brazilian current management practices that happen in constructor firm-subcontractor relationship are described, as well as a parallel with the case of Great Britain. About stimulating cooperation networks in the sector, some actions are also quoted.

It can be said that supply chain integration in a cooperation network through strategic partnering is a key success factor for increasing competitive advantages in the sector.

KEYWORDS

Supply chain management, subcontractor, cooperation network, lean construction, building construction.

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INTRODUCTION

Lean production consists of a complex cocktail of ideas, including continuous improvement, lean organization structures, teamwork, elimination of waste, efficient use of resources and cooperative supply chain management. These aspects have been challenged by authors like Koskela (1992) and Howell and Ballard (1994), and discussed by others, like Green (1999) and Garnett *et al.* (1998).

Koskela (1992) was a pioneer in applying lean production ideas to construction. He proposed the need to understand construction production as a combination of conversion and flow processes and not as a mere number of disjointed conversion processes.

Lean construction philosophy deals with the production process and aims at the adoption of methodologies that allow for the attainment of favorable results in terms of generation of aggregate value to product, without implying cost increase or quality loss. It relies on five principles of the Lean Thinking philosophy: value, value stream, flow, pull and perfection (Womack and Jones 1996). As consequences of the implementation of this philosophy, the following can be mentioned: systematic waste reduction, operational costs reduction and attainment of commitment and teamwork qualification (Contador 1998). The central themes of lean construction have been eliminating waste and improving workflow in construction (London and Kenley 2001).

According to Amato Neto (1999), some changes in the modern capitalist world, such as the emergence of new technologies, imposed changes in the organizational structure of enterprises. In this context, the advent of the lean production paradigm has produced new kinds of inter-firms relationships. One form of inter-firm relationship is cooperation network among companies operating within the same production chain, which can create synergy of positive impacts, the so-called ‘collective efficiency’[3].

Even if the lean production concepts are more related to the firms themselves, in the ‘micro’ level, they can be extended to the ‘*mezzo*’ or medium one, concerning relationship between firms, in an industry. This relationship deals with market aspects, but also with general ones, like technology, organization, manpower, design, etc.

In this way, the purpose of this paper is to stimulate discussions about the decision of make or buy (subcontracting) and about the constitution of cooperation networks in construction industry and also to highlight the importance of partnering for building industry improvements. The study is based on the analysis of a large number of publications about correlated subjects.

Focusing mainly on subcontractors and building constructors, this paper seeks to discuss two types of partnering (project and strategic) and to analyze its importance in formation and development of cooperation networks in building construction.

LITERATURE REVIEW

VERTICAL INTEGRATION

Vertical integration involves a variety of decisions concerning whether corporations, through their business units, should provide certain goods or services in-house or purchase

[3] Hubert Schimitz defines collective efficiency as the competitive advantage derived from local external economies and joint action. See more details in Schimitz, H. (1995). "Collective Efficiency: Growth Path for Small-Scale Industry". *The Journal of Development Studies*, 31 (4), 529-566.

them, instead (Harrigan 1985). The strategy of vertical integration consists in defining if a company will make or buy its basic inputs and jobs.

Porter (1980) defines vertical integration as the production processes combination, distribution, sales and/or other distinct production processes within the borders of the same company.

The general question of vertical integration is the extent to which a firm is directly responsible for producing all of the inputs required for its products (Eccles 1981). Thus, if the company decides to acquire some inputs from other firms, the main question turns into the efficient management of these relationships.

Among the benefits of vertical integration are: reduction of transaction costs[4], guaranteed supply of features, improved internal coordination, broader technological capacity and biggest difficulty of entering the market (Buzzell 1983).

The disadvantages of vertical integration are: need of high investments, flexibility reduction to demand, variation of market and specialization loss, because the organization is concentrated on some production processes, still according to the same author.

The adequate development of the integration strategies, according to Krippaehne (1992), requires the following actions by the firms:

- to prevent the internal development of capacities that can be satisfied by external firms;
- to develop good relations with the group of subcontractors and suppliers they work with;
- to appeal to other pre-qualified firms to monitor the conditions of market price and technology;
- to reduce its amount of work performed with proper features, disintegrating in some way, mainly in the case of those with low profit margin;
- to be aware that, whichever the strategy adopted, it must be constantly revised.

Harrigan (1983) describes four generic strategies of vertical integration, each with different degrees of transferences and different internal investments and each implying bargaining power with adjacent industries. These strategies are described as follows:

- *Full integrated strategies:* the fully integrated firms internally buy or sell all of their requirements for a particular material or service internally. They have the highest degree of internal integration (Harrigan 1983).
- *Taper-integrated strategies:* taper-integrated firms rely on outsiders for a portion of their requirements. Taper integration means that the firm purchases or sells the remainder through specialized supplier, distributor, or competitors that are not so integrated (Harrigan 1983).

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4 Transaction costs are the costs of running the economic system, or simply the costs of carrying out any exchange, whether between firms in a marketplace or a transfer of resources between stages in a vertically integrated firm. They are the economic equivalent of friction in physical systems. See more details in Williamson, O.E. (1985). *The Economic Institutions of Capitalism - Firms, Markets, Relational Contraction*. New York, The Free Press. See also Hobbes, J.E. (1996). "A Transactional Cost Approach to Supply Chain Management". *Supply Chain Management,* 1 (2), 16-27.

- *Quasi-integration:* quasi-integrated firms need not own 100 percent of the adjacent business units in question, but they may consume or distribute all, some, or none of the outputs or inputs of the adjacent, quasi-integrated unit (Harrigan 1983).
- *Nonintegrated strategies:* firms simply buy raw materials or assemblies as needed.

SUBCONTRACTING

Subcontracting has been presented as an organizational alternative for some economic activities (Beardsworth 1988). Firms are decentralizing their jobs more and more, allowing subcontracting to become a basic part of the work organization.

Veltz (2000) points out that the firm does not need to have the control of all the value string, being able to externalize non-strategical activities, aiming to reduce costs.

Pagnani (1989) defines subcontracting as a legal-economic relationship between two agents, in which the characteristic criteria are substitution and subordination. The substitution criterion means that the subcontractor executes the operation with technical and financial risks, instead of the job assignor; the subordination criterion means the subcontractor must follow the direction given by the contractor.

Some main aspects involved in job subcontracting, for the case of buildings construction, are analyzed in Table 1.

Table 1: Aspects of subcontracting in building construction

Aspects	Comments
Flexibility	Subcontracting appears as an answer to market uncertainties.
Quality	Subcontracting, on the one hand, can improve product quality because it uses specialized manpower and, on the other hand, can get worse, because it leads to problems of control and coordination.
Costs	Fixed costs become smaller, while transaction costs increase. Fixed costs are lesser because subcontracting eliminates equipment maintenance and underutilized manpower. Transaction costs can become bigger, because each new contract negotiation can involve some proposals by subcontractors.
Productivity	Subcontracting tends to further tie the laborer to the firm subcontractor. Thus, the effects of replication, continuity and learning lead to higher productivity by the manpower. Easy access to specialized equipment and constant training also lead to higher productivity.
Controls	Controlling the quality of work is difficult with subcontracting, because the high amount of independent organizations in the site makes the control of work progress difficult.
Planning	The intensive subcontracting of manpower makes the planning process difficult. Moreover, conflicting interests can intervene negatively with the programming of activities.
Technology	Market instability leads the contracting firms not to establish stable agreements with the subcontractors, thus not allowing technology transfer.
Training	The contractors tend to pass the responsibility of training to the subcontractors, but generally they are not apt to accomplish it, due to financial features and the lack of time for training.
Safety at work	The final responsibility for the safety at work falls on the contracting company, as well as the implementation of a safety program, the commitment and supervision of the subcontractors. The disinterest of the contractor in investing in programs of safety for floating and unknown workers and the lack of familiarity of the workers with the working atmosphere aggravates this problem.
Consumption of materials	Subcontracting can magnify materials waste; subcontractors tend to finish the job as fast as possible, without controlling the use of materials.

Adapted from Shimizu and Cardoso (2002).

According to Bennett and Ferry (1990), building firms are organized into a consistent operating core based on their individual capabilities. Construction companies are becoming construction managers or contractor managers, transferring construction work to specialists.

Subcontractors are specialist agents in the execution of a specific job, supplying manpower, besides materials, equipment, tools or designs. They respond only for the executed part of the workmanship, acting as agents of the production system of the contractor company.

According to Tommelein and Ballard (1997), specialty contractors are construction 'job shops', performing construction work that requires skilled labor from one or at most a few specific trades and for which they have acquired special-purpose tools and equipment as well as process know-how.

In the United States, in many projects, particularly building projects, it is common for 80-90% of the work to be performed by subcontractors (Hinze and Tracey 1994). Villagarcia and Cardoso (1999) state that during the last years subcontracting has increased in Sao Paulo (Brazil), and it is known that, to date, subcontracting achieves similar levels to the ones mentioned by Hinze and Tracey.

Subcontractors classification focuses on the kind of activities they perform. Table 2 shows three types of classification of subcontractors in building construction, organized by Brazilian authors.

Table 2: Classification of subcontractors in building construction.

Author	**Classification**	**Examples activities**
Farah (1993)	*subcontractors of basic activity*	formwork, mortar, concrete, masonry, rendering and ceramic coatings
	subcontractors of stages and specialized jobs	jobs done by workers with specific qualifications
Villacreses (1994)	*subcontractors of basic*	activity formwork, mortar, concrete, masonry, rendering and ceramic coatings
	subcontractors of special techniques	electric fittings, plumbing, air conditioning
	subcontractors of special work and/or materials	external waterproofing, painting, floor, glasses, external rendering, foundations
Pereira (2001)	*subcontractors supplying manpower*	masonry, painting
	subcontractors supplying manpower and materials	electric fittings, plumbing, joinery
	subcontractors supplying manpower, materials and designs	waterproofing, gypsum wallboard
	subcontractors supplying manpower, materials, designs and maintenance	air conditioning, sprinkler-system, special fittings

Adapted from Farah (1993), Villacreses (1994) and Pereira (2001).

Note that in Pereira's classification there is an enlargement of the subcontractors role from the first to the last type. This classification seems to be more appropriate for the purpose of this paper.

PARTNERING

Partnering has been seen as a tool for improving the performance of the construction process and emphasizes the way it helps to create synergy and maximize the effectiveness of each participant's resources (Barlow *et al.* 1997).

The Construction Industry Institute defines partnering as *a long-term commitment between two or more organizations for the purpose of achieving specific business objectives by maximizing the effectiveness of each participant's resources. This requires* *changing traditional relationships to a shared culture without regard to organizational boundaries. The relationship is based upon trust, dedication to common goals, and an understanding of each other's individual expectations and values* (Barlow *et al.* 1997).

To date, partnering is understood as a set of collaborative processes, which emphasizes the importance of common goals. The base of partnering is a high level of interorganisational trust and the presence of mutually beneficial goals. Partnering means a management process that helps the strategic planning to improve the efficiency of the enterprises, and forms a team with common objectives (Barlow *et al.* 1997).

Participants of a project can improve performance in terms of cost, time, quality, buildability, fitness-to-purpose and a whole of range of other criteria, if they adopt more collaborative ways of working (Bresnen and Marshall 2000). According to the same authors, partnering aims to reduce the adversarialism which is said to be typical in the industry and which has confounded previous attempts to encourage better integration and cooperation between contractual partners.

Barlow *et al.* (1997) mention six successful factor of partnering: building trust, teambuilding, the need for top level commitment, the importance of individuals, the strategic movement of key personnel, and the need of open and flexible communications. The same authors quote as common benefits in a partnering relation: reduced costs, shortened delivery time, improvement in construction quality, better working atmosphere, and organizational learning.

Partnering classification focus on the duration of cooperation between partners. Two main types of partnering are found in literature: project partnering and strategic partnering or long-term partnering.

Project partnering is a cooperative relationship between organizations for the duration of a specific project (Barlow *et al.* 1997). At the end of the project, the relationship is terminated and another partnering may commence on the next project (Kumaraswamy and Matthews 2000). Welling and Kamann (2001) state that if these firms do not meet again in another project, the learning effect reached on the particular project will be eliminated.

Strategic partnering is a relationship with a high level of cooperation between partners (Barlow *et al.* 1997), which takes place when two or more firms use partnering on a long-term basis to undertake more than one construction project, or some continuing activity (Kumaraswamy and Matthews 2000). In this kind of partnering, the learning achieved in a specific project is more likely to be used in future projects.

In the context of a strategic partnering, it becomes a management philosophy that is expected to work continuously for each and every project and there are more expectations from team members than for a project partnering (Cheng and Li 2001).

COOPERATION NETWORK

The term network refers to a set of nodes and relationships that are connected. Grandori and Soda (1995), focusing on organizational theory, see networks as nexuses of integration mechanisms encompassing all the range of organizational inter-firms coordination and cooperation. The proposition is that networks compete with networks, rather than simply firms with firms. It follows that networks encompass both upstream and downstream firms (Lamming *et al.* 2000).

In consummate cooperation, both parties work together to a mutual end, responding flexibly, sharing skills and information (Welling and Kamann 2001).

Networks differ in terms of degree of complexity, concentration of power balance, environmental diversity and stage of network development (Harland *et al.* 2001). Grandori and Soda's (1995) classification centers on power balance and divides networks in: (1) symmetric, parity-based or equity networks and (2) asymmetric, centralized or non-equity networks. Williamson (1985) classifies networks according to their behavior: (1) opportunistic networks and (2) non-opportunistic networks. These classifications are important because they will influence the way a firm can manage its cooperation network, as discussed below.

COOPERATION NETWORKS FORMATION AND DEVELOPMENT

BUSINESS RELATIONSHIPS IN CONSTRUCTION INDUSTRY

The construction industry is dependent on subcontractors and on suppliers of building materials. However, it is characterized by opportunistic behavior and the lack of vertical cooperation (Welling and Kamann 2001). This happens because of the industry traditional approach of the organizational structure of the construction process, which results in a subordinate position for subcontractors within the hierarchy of relationships forming the traditional design-management-construction process. Consequently, main contractor-subcontractor relationships are often found to be strained and adversarial (Dainty *et al.* 2001).

The French project organization seems to be a particular case. Winch and Campagnac (1995) call it 'co-contracting', where *the principal contractor is directly responsible for the structural works, which it carried out mainly with its own directly employed work-force* and where *the finishing trades contractors are placed in direct contact with the client and the principal contractor is paid a fee for their management*.

Construction industry, compared with others, lags behind in terms of cooperation. However, some care must be taken when comparing construction with other industries (Welling and Kamann 2001):

- The governance of transactions in construction supply chain differs from mass assembly and process technologies.
- Construction is not one supply chain, but a series of distinct chains, with unique properties that are complex and difficult to coordinate.
- Construction projects require a unique combination of labor and material inputs, performed and coordinated on site, lacking controlled factory environments.
- Organization and management of a construction project almost invariably involves interlinkages among a number of organizations. These organizations generally differ in size, culture, skill level, specialty, automated information systems and methods of production control.

Eccles (1981) points out that all of these organizations have to cooperate in some way in order to combine their resources. At a certain time, a number of these organizations will be simultaneously involved in the project and, given the dependence path of activities, the work of one firm cannot proceed until the work of several others has been completed.

PARTNERING IMPORTANCE FOR COOPERATION NETWORKS

Studies of customer-supplier collaboration have shown that major benefits may be achieved when firms adapt to one another (Dubbois and Gadde 2000).

Corbett *et al.* (1999) state that failing to collaborate results in the distortion of information, which can lead to costly inefficiencies. Through a more open, frequent and accurate exchange of information, typical of a strategic partnering, companies can eliminate many of these problems and ensure ongoing improvement.

Howell (1999) points out that partnering provides the opportunity for collaborative redesign of the planning system to support close coordination and reliable workflow. Nevertheless, this author also says that partnering without a change in project and production management philosophy typically fails, because the mere act of partnering does not change the way the work is done.

The development of trust between organizations is seen as a function of the length of the relationship between them, and the mechanisms that led to this alignment (repetition, routine, understanding) are largely viewed as informal (Bresnen and Marshall 2000).

Although the advantages of project partnering are not regarded as equal to strategic partnering, the fact that it is considered possible to cause change over the timescale of a single project is indicative of the view that partnering can be engineered and does not have to evolve 'naturally' (Bresnen and Marshall 2000).

Thus, in the short term, contractors may be willing to absorb any extra costs in order to develop or maintain a relationship. However, such an approach may be unsustainable in the long run (Bresnen and Marshall 2000).

In rival networks, firms may behave opportunistically, gaining at the expense of other firms. These networks play a zero-sum game, i.e. a situation where for one party to gain, another must lose (Jones 1990). Jones still points out that most networks are rivals, basing decisions primarily on price.

CURRENT PRACTICE

Brazil

In this item, based on Shimizu and Cardoso (2002), the Brazilian current management practices that happen in constructor firm-subcontractor relationship are characterized.

As some Brazilian authors like Serra (2001) have already signaled, subcontractors are generally subordinated to the wills of the constructors, in which the imposition of the decisions of the latter prevails most of the time. In general, subcontractors can only choose between 'accepting the agreement job' according to criteria defined by the constructor or 'to refuse the job'. About the selection of subcontractors, the market focuses only on price.

About the relation between constructors and subcontractors, one is dissatisfied with the other: on the one hand, constructors state that the low organizational level of subcontractors makes the relation difficult; on the other hand, subcontractors assure that constructors usually take advantage of high competition to impose low prices. As Pereira (2001) has shown, this conflict can go beyond the contract phase, and is kept all along the project. This is particularly true in the case of subcontractors belonging to the two first levels of Pereira's classification, presented in Table 2, but less evident in the case of subcontractors supplying manpower, materials, designs and maintenance.

Excluding relationships concerning this last type of subcontractors, the lack of partnering relations between Brazilian contractors and subcontractors is noted. Nevertheless, this characteristic can rapidly change, as subcontractors tend to enlarge their role in the construction process, also supplying materials, design and maintenance.

A parallel: Great Britain

Brazilian reality is similar to that of other countries. Dainty *et al.* (2001) conducted a research with 20 subcontractors in Great Britain and concluded that companies interviewed generally held negative views of partnering and believed that some main contractors did not understand the principles of partnering and strategic alliances, or that their motivations for adopting such practices were not for reasons of engendering mutual trust.

The same authors add that directors of subcontractors viewed partnering, such as open-book accounting, merely as mechanisms for main contractors to drive down their profits. They also state that the barriers identified were seen as being symptomatic of a lack of understanding and empathy with subcontractors' needs by main contractors, particularly with regard to cost and payment issues.

Another conclusion of the Dainty *et al.* research was that subcontractors blamed the lack of trust between the parties on the adversarial nature of their working relationships that had characterized the industry operation for many years. Indeed, the cultural issue of mistrust between the parties was seen as a fundamental barrier to increase understanding of each other's needs and to further integration.

Therefore, rethinking the production system design according to lean construction philosophy can be a good opportunity to change the organizational structure of the players, this being a prerequisite for successful partnering. The question is how multi-organizational structures should be designed to effectively execute lean production systems and bring together contractors and subcontractors.

According to Welling and Kamann (2001), construction firms do not seem to take advantage of opportunities to make use of external resources through new organizational forms, such as cooperation, networking and strategic alliances, which are increasingly emphasized as critical factors in successfully running organizations.

This lack of cooperation is influenced by some surrounding economic conditions, like focus on price, short term vision and great competition, which predispose contractual partners to act, for a very rational economic reason, in more 'traditional', adversarial and even exploitative ways.

Many problems referred directly and indirectly to insufficient coordination, communication, and thus commitment, such as failures to inform about schedule changes, late information of deliveries, and lack of feedback procedures (Vrijhoef *et al.* 2001), mainly related to failures in the production system.

However, it is important to list some good experiences related in literature. One example is Barlow *et al.* (1997), whose research explored the managerial process involved in five client-led partnering arrangements, encompassing over 40 firms.

STIMULATING COOPERATION NETWORKS

The central tenet of the building industry is that the greater provision of integration will solve many of the problems that fragmentation has caused within the sector (Dainty *et al.* 2001). The key barriers to greater integration seem to stem from the historical fragmentation of project delivery system, and the contractual and adversarial nature of construction project relationships.

Some arguments in the literature state that not only the players themselves are in charge of such integration. Dainty *et al.* (2001) have signaled the role of those at the head of the production process, pointing towards two specifics needs for better integration: a greater degree of client leadership in order to drive the integration process and an insistence on transparent and mutually beneficial processes for all parties in the supply chain.

Another important issue is minimizing conflicts arousing from these relations. Welling and Kamann (2001) recommend the following actions for the management of these relations in the construction:

- Structuring relationships in such a way that there are frequent and durable interactions among specific individuals.
- Appointing account managers and asking firms that are part of the permanent network to do the same should create recurrent meetings among people and this, in turn, should stimulate cooperative relations.
- Monitoring current behavior and experiences and pooling this information enables project managers to share experiences.

CONCLUSIONS

This paper has given a brief, and by no means exhaustive, overview of some of the main issues arising from current research on cooperation network.

The need of strategies analysis that makes the construction sector more competitive is noticed. Amongst these strategies, the vertical disintegration (subcontracting) appears as a good alternative, providing flexibility, lean structures, productivity, and costs reduction, amongst other advantages.

The use of partnering appears as a possibility of getting the advantages and reducing the disadvantages of subcontracting, through the maintenance of stable and beneficial relationships. It is clear that the advantages of project partnering are not regarded as equal to strategic partnering, but a project partnering has its benefits. Besides, a project partnering may evolve to a strategic partnering in the future. Even if a relationship between firms does not automatically make it a 'perfect team', there is always the potential. Teams develop as the involved parties experiment with various connections and learn from the developments. This is particularly important in Brazil, where subcontractors tend to expand their role in the construction process.

Although there are some good examples of strategic partnerships that have led to considerable improvements in construction project delivery (see Barlow *et al.* 1997) these have been largely restricted to client-contractor linkages, as opposed to developing strategic alliances throughout all the supply chain.

The truth is that strategic partnering alliances are not frequent in the construction industry and that cooperation network is a concept that is very far from current management practices in this sector.

An effective integration is unlikely to be possible without fundamentally rethinking the current inter-organization relationships and dynamics that exist within the construction industry. A change in this situation will require main contractors to make efforts to address the integration and partnership of smaller companies as well as client organizations. Even if the lean construction concepts are more related to firms, they can be extended to this level, as some authors mentioned in this paper have already done.

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WHAT IS LEAN CONSTRUCTION - 1999

Gregory A. Howell[1]

ABSTRACT

The origins of lean production are reviewed and a claim made that it is a new form of production management, that is neither mass nor craft. Then the applicability of lean production in construction is considered and nature of lean construction discussed in comparison with current practice.

KEY WORDS

Lean construction, lean production, production management

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INTRODUCTION

Lean construction much like current practice has the goal of better meeting customer needs while using less of everything. But unlike current practice, lean construction rests on production management principles, the "physics[1]" of construction. The result is a new project delivery system that can be applied to any kind of construction but is particularly suited for complex, uncertain, and quick projects.

HISTORY OF LEAN PRODUCTION

Lean production was developed by Toyota led by Engineer Ohno. He was a smart if difficult person dedicated to eliminating waste. The term "lean" was coined by the research team working on international auto production to reflect both the waste reduction nature of the Toyota production system and to contrast it with craft and mass forms of production (Womack et al. 1991). Engineer Ohno shifted attention to the entire production system from the narrow focus of craft production on worker productivity and mass production on machine. Ohno followed the work of Henry Ford and continued the development of flow based production management. But unlike Ford who had an almost unlimited demand for a standard product, Ohno wanted to build cars to customer order. Starting from efforts to reduce machine set up time and influenced by TQM, he developed a simple set of objectives for the design of the production system: Produce a car to the requirements of a specific customer, deliver it instantly, and maintain no inventories or intermediate stores.

Waste is defined by the performance criteria for the production system. Failure to meet the unique requirements of a client is waste, as is time beyond instant and inventory standing idle. A morning cup of coffee serves as an example. Instant delivery is possible but we must either have an intermediate inventory, coffee in the pot, or accept a cup of "instant" which hardly meets requirements of someone craving a low-fat double latte.

Moving toward zero waste, perfection, shifts the improvement focus from the activity to the delivery system. Engineer Ohno and other Japanese engineers were familiar with mass production of cars from their plant visits in the United States. Where US managers saw efficiency, Ohno saw waste at every turn. He understood that the pressure to keep each machine running at maximum production led to extensive intermediate inventories he called "the waste of over production." And he saw defects built into cars because of the pressure to keep the assembly line moving. Production at all costs meant defects were left in cars as they passed down the line. These defects disrupted down stream work and left completed cars riddled with embedded defects. Where the US approach aimed to keep the machines running and the line moving to minimize the cost of each part and car, Ohno's system design criteria set a multi-dimensioned standard of perfection that prevented sub-optimization and promoted continuous improvement.

Zero time delivery of a car meeting customer requirements, with nothing in inventory required tight coordination between the progress of each car down the line and the arrival of

[1] The idea of a "physics" of production is borrowed from "Factory Physics", an excellent text on production management (Hopp and Spearman 1996).

parts from supply chains. Rework due to errors could not be tolerated as it reduced throughput, the time to make a car from beginning to end, and caused unreliable workflow. And coordinating the arrival of parts assigned to a particular car would be impossible if the movement of the car was unreliable.

Engineer Ohno went so far as to require workers to stop the line on receipt of a defective part or product from upstream. (Only the plant manager could stop the line in US plants.) Working to eliminate rework makes sense from a system perspective, but stopping the line looks very strange to people who are trying to optimize performance of a single activity. Stopping the line made sense to Ohno because he recognized that reducing the cost or increasing the speed could add waste if variability was injected into the flow of work by the "improvement."

Requiring workers to stop the line decentralized decision making. He carried this further when he replaced centralized control of inventory with a simple system of cards or bins which signaled the upstream station of downstream demand. In effect, an inventory control strategy was developed which replaced central push with distributed pull. Pull was essential to reduce work in process (WIP). Lower WIP tied up less working capital and decreased the cost of design changes during manufacture as only a few pieces needed to be scrapped or altered. Large inventories are required to keep production in push systems because they are unable to cope with uncertainties in the production system. And large inventories raise the cost of change.

Ohno also decentralized shop floor management by making visible production system information to everyone involved with production. "Transparency" allowed people to make decisions in support of production system objectives and reduced the need for more senior and central management.

As he came to better understand the demands of low waste production in manufacturing, he moved back into the design process and out along supply chains. In an effort to reduce the time to design and deliver a new model, the design of the production process was carefully considered along with the design of the car. Engineering components to meet design and production criteria was shifted to the suppliers. New commercial contracts were developed which gave the suppliers the incentive to continually reduce both the cost of their components and to participate in the overall improvement of the product and delivery process. Toyota was a demanding customer but it offered suppliers continuing support for improvement.

Lean production continues to evolve but the basic outline is clear. Design a production system that will deliver a custom product instantly on order but maintain no intermediate inventories. The concepts include:

- Identify and deliver value to the customer value: eliminate anything that does not add value.
- Organize production as a continuous flow.

- Perfect the product and create reliable flow[2] through stopping the line, pulling inventory, and distributing information and decision making.
- Pursue perfection: Deliver on order a product meeting customer requirements with nothing in inventory.

Lean production can now be understood as a new way to design and make things differentiated from mass and craft forms of production by the objectives and techniques applied on the shop floor, in design and along supply chains. Lean production aims to optimize performance of the production system against a standard of perfection to meet unique customer requirements.

LEAN CONSTRUCTION

Lean construction accepts the Ohno's production system design criteria as a standard of perfection. But how does the Toyota system, lean production, apply in construction? The construction industry has rejected many ideas from manufacturing because of the belief that construction is different. Manufacturers make parts that go into projects but the design and construction of unique and complex projects in highly uncertain environments under great time and schedule pressure is fundamentally different from making tin cans.

Lean production invites a closer look. Certainly the goal of a delivering a project meeting specific customer requirements in zero time sounds like the objective for every project, and the evidence of waste in Ohno's terms is overwhelming. Waste in construction and manufacturing arises from the same activity-centered thinking, "Keep intense pressure for production on every activity because reducing the cost and duration of each step is the key to improvement." Ohno knew there was a better way to design and make things.

Managing construction under Lean is different from typical contemporary practice because it;

- has a clear set of objectives for the delivery process,
- is aimed at maximizing performance for the customer at the project level,
- designs concurrently product and process, and
- applies production control throughout the life of the project.

By contrast, the current form of production management in construction is derived from the same activity centered approach found in mass production and project management. It aims to optimize the project activity by activity, assuming customer value has been identified in design. Production is managed throughout a project by first breaking the project into pieces, i.e. design and construction, then putting those pieces in a logical sequence, estimating the time and resources required to complete each activity and therefore the project. Each piece or activity is further decomposed until it is contracted out or assigned to a task leader, foreman or squad boss. Control is conceived as monitoring each contract or activity against its schedule and budget projections. These projections are rolled up to project level reports. If

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[2] Reliable workflow was a consequence of stopping the line rather than a stated objective.

activities or chains along the critical path fall behind, efforts are made to reduce cost and duration of the offending activity or changing the sequence of work. If these steps do not solve the problem, it is often necessary to trade cost for schedule by working out of the best sequence to make progress. The focus on activities conceals the waste generated between continuing activities by the unpredictable release of work and the arrival of needed resources. Simply put, current forms of production and project management focus on activities and ignore flow and value considerations (Koskela 1992, Koskela and Huovila 1997).

Managing the combined effect of dependence and variation is a first concern in lean production. Goldratt (1986) illustrates the effects on production in "The Goal" and the application to construction is demonstrated by Tommelein et al. (1999) in "Parade of Trades. The problem of dependence and variation can be illustrated by what happens in heavy traffic on a freeway. If every car drove at exactly the same speed then spacing between cars could be very small and the capacity of the freeway would be limited by whatever speed was set. Each car would be dependent on the one ahead to release pavement and variation would be zero. In effect, there would be no inventory of unused pavement. In reality of course, each car does use the pavement released to it from the car ahead but speeds vary.

Under the pressure to get to work or home, gaps between cars close and any variation in speed demands immediate response from following cars. As the gaps close, small variations in speed propagate along and across lanes. One small hesitation can lead to a huge standing wave as traffic slows to a crawl. Recovery is difficult because it is impossible to get everyone to accelerate smoothly back up to the standard speed and interval. High speed at any one moment does not assure minimum travel time in conditions of dependence and variation. The idea that you do not get home any faster by driving as fast and as close to the car ahead is counter intuitive (at least to teenagers). Certainly the system itself does not function as well when dependence is tighter and variation greater.

Managing the interaction between activities, the combined effects of dependence and variation, is essential if we are to deliver projects in the shortest time. Minimizing the combined effects of dependence and variation becomes a central issue for the planning and control system as project duration is reduced and the complexity increases. (Complexity is defined by the number of pieces or activities that can interact.) The need to improve reliability in complex and quick circumstances is obvious. New forms of planning and control are required.

The first goal of lean construction must be to fully understand the underlying "physics" of production, the effects of dependence and variation along supply and assembly chains. These physical issues are ignored in current practice which tend to focus on teamwork, communication and commercial contracts. These more human issues are at the top of practitioner's lists of concerns because they do not, indeed cannot see the source of their problems. It is not that these people are stupid, but that they lack the language and conceptual foundation to understand the problem in physical production terms. The development of partnering illustrates this point.

Partnering makes great sense from an activity perspective. But few realize Partnering is a solution to the failure of central control to manage production in conditions of high uncertainty and complexity. In these circumstances, representatives of each activity (or contract) must be able to communicate directly with out relying on the central authority to control message flow, and so Partnering works. From the lean understanding of the physics of production, Partnering is evidence of a failure in production management but it provides the opportunity for collaborative redesign of the planning system to support close coordination and reliable work flow.

Lean supports the development of team work and a willingness to shift burdens along supply chains. Partnering relationships coupled with lean thinking make rapid implementation possible. Where Partnering is about building trust, lean is about building reliability. Trust is the human attitude that arises in conditions of reliability. We are not likely to trust one another very long if we do not demonstrate reliability. Reliability is the result of the way systems are designed. Of course people manage systems and in current terms they do a fine job. The problem is that production systems just do not work well when every person tries to optimize their performance without understanding how their actions affect the larger web.

The problem of matching labor to available work offers a good example of the difference between the contemporary view of the workplace and lean. "Matching labor to work" means having the resources on hand for a crew to work steadily and without interruption. Current practice views the assignment to the crew as a sort of "mini contract" which is more or less independent of other assignments, and sets the person in charge responsible for the organization of resources and direction of the crew. To be fair, companies have logistics systems that try to get the resources close to the crew and a few actually try to assemble and assign packages of work. But the majority of foremen are responsible for the final collection of resources and assuring that their crews can work continuously. When this approach fails to produce acceptable results, when the numbers are bad, management assumes the foreman or crew is not performing.

Companies typically maintain elaborate cost control systems to measure this performance. These systems are the manifestations of the cause and effect theories operating in the company. At the heart of this model is the belief that the crew is essentially independent and that all costs charged to an account arise within from the effort necessary to complete the assignment by the crew.

The lean construction view is different as it views the problem in physical production terms. The crew works at variable rates using resources supplied at varying rates. Matching labor to available work is a difficult systems design problem with a limited number of "solutions." Lean works to isolate the crew from variation in supply by providing an adequate backlog (a safe distance between cars) or tries to maintain excess capacity in the crew so they can speed up or slow as conditions dictate. On occasion, people acting on intuition apply these techniques. (They drive to work on freeways.) Unfortunately neither resource nor capacity buffers reduce the variation in supply and use rates of downstream crews.

These problems are solved by long and predictable runs in the factories (and along the highways of our dreams). In these stable circumstances managers can predict the work content at each station and shift labor along the line to minimize imbalance. Such factories are mostly dreams that have little to do with construction where we only have some idea of the labor content of activities from previous projects.

People holding current practice dear sometimes say they are helpless victims of fate when faced with managing uncertainty on projects. Their view is that uncertainty arises in other activities beyond their control. The lean approach is to assure we do not contribute to variation in work flow and to decouple when we cannot get it under control. In lean construction as in much of manufacturing, planning and control are two sides of a coin that keeps revolving throughout a project.

- **Planning:** defining criteria for success and producing strategies for achieving objectives.
- **Control:** causing events to conform to plan and triggering learning and re-planning.

Often the first question we are asked when describing a project to people unfamiliar with lean thinking is, "What kind of contract was in force?" Next come organizational and systems issues: "Was supervision by area or craft? Union or not? Were designers on site? Did the owner know what they wanted?" These questions are reflections of contracting or activity centered thinking. Lean construction rests on a production management mind. We ask about the way work itself is planned and managed. We want to know the whether the planning system itself is under control, the location of inventories and excess capacity, and the extent to which the design and construction process itself supports customer value.

Lean construction embraces uncertainty in supply and use rates as the first great opportunity and employ production planning to make the release of work to the next crew more predictable, and then we work within the crews to understand the causes of variation.

Where current practice attacks point speed, lean construction attacks variation system wide.

Under lean, labor and work flow are closely matched when variation is under control and activities de-coupled through capacity or resource buffers when variation is not under control and work content unbalanced. These solutions are directed by the physics of the situation. Where current practice assesses and attempts to control individual performance, we see the planning system as the key to reliable work flow. Construction is different from manufacturing in the way work is released to the crew. Work is released, moves down the line, in manufacturing based on the design of the factory. In construction work is released by an administrative act, planning. In this sense, construction is directives driven and so measuring and improving planning system performance is the key to improving work flow reliability. Measuring planning system performance reflects our understanding of cause and effect. This is a different mind, a new novel. Once we understand physics problems at the crew level, we see all sorts of new issues and opportunities.

Our first objective is to bring the flow of work and production itself under control. This effort pays immediate dividends and demands the project delivery system be changed to better support reliable work flow. These include changing how work is structured early in design, and the organization and function of both the master project plan and lookahead process (Ballard and Howell 1997).

Research proposed by the Lean Construction Institute follows this path. We start with working to understand the physics of production at the task level, and then to design the underlying systems to support high performance in Ohno's terms. The planning system is the logical first target, but other design, procurement and logistic systems must also be considered. We understand that it will be necessary to change the organization to support these redesigned systems. Here we take another page from Ohno and expect to see distributed control replace current reliance on central control. Research efforts now underway explore the application of pull techniques both on site and in design. Finally, we expect new forms of commercial contract to emerge that give incentives for reliable work flow and optimization at the deliverable-to-the-client level. In this way we move from task to system to organization to contract.

Human issues come into play on implementation. Systems, teams, organizations, communication and contracts do not change the physics. Their design does limit what can happen just as physical rules place other limits. For example, the need for upstream investment to reduce downstream variation is in conflict with current practices of buying each piece for the lowest cost, or of pushing each crew to work quickly as opposed to reliably. Uncertainty in work flow places great demand on communication channels as people attempt to find some way to keep the project or their crew moving in the face of uncertainty. But flexibility defined in this way requires slack resources and injects more uncertainty into the flow of work. Where we see uncertainty as the consequence of the way we manage work, they see uncertainty as environmental and beyond their control. We operate on different theories, we tell different stories.

A pattern is beginning to emerge in implementation. Managers in most companies and on most projects have an inflated view of the reliability of their planning system. This attitude changes once the decision is taken to make assignments to criteria and the results come in. New opportunities are revealed and new demands arise in all directions. Upstream changes typically include changes in the timing and size of deliveries from fabricators. Horizontally, coordination with other specialty contractors shifts from a central controlled push functions to decentralized pull. Downstream, the effect of reliable work flow may be to change the way labor is managed. One contractor now shifts labor between nearby projects because it is possible to predict the actual demand for labor in coming weeks. Hoarding labor is reduced and fewer workers can service more jobs.

"Value" is one area of our work that does not rest so directly on some underlying physics. Here we are trying to understand how value is created. We believe our work will help organize and frame the conversation between ends and means so that the implications of early decisions are more explicit. We expect to change the design process so it will better cope with the contending demands of uncertainty and speed, and respond to the explosion in available technology.

RESEARCH AND THE LEAN CONSTRUCTION INSTITUTE

The Lean Construction Institute (LCI) is theory driven and theory seeking. We think nothing is more practical than a good theory, as it explains what happens and why. For example, in current practice a delay is often attributed to morally deficient subcontractors[3].

Our theory is that such delays may be due to the combined effects of dependence and variation working over a long supply chain and period. We can test this theory by experimenting with techniques that reduce dependence and variation and observe the results. New theory, that is new cause and effect models, are invisible to those holding current theories dear. We approach problems related to production in construction first in physical and then systems terms believing that issues of organization and contract can only be resolved by assuring they best manage the "physics" of production. This approach is in contrast with efforts that start with issues of motivation and contract and never to come to grips with the work itself.

In each case we first want understand the current state of knowledge, and then form our theories. In this stage we must understand how the function is accomplished in current practice and the underlying mental model or theory that supports that practice. We cannot improve what we don't understand [insert comma] so accurate description is the first step in solving the puzzle. Other pieces may be found in the literature, current practice, theory or practice in related fields or the application of logic while taking a shower. Once we assemble the pieces a new theory is revealed and we can design experiments and refine our thinking.

Common sense teaches us to break large problems into parts small enough to be solved. We are taught "the devil is in the details", and he often is. Traditional research and science, like contemporary forms of project management, is built on this reductionist approach. The LCI research agenda does not ignore the details or the resulting common sense. But LCI is aligned with new forms of enquiry that are attempting to understand how and why "The whole is more than the sum of its parts." It is here in complex uncertain and quick circumstance that we expect to make explicit the roots of conventional wisdom, make our contributions, and redefine common sense.

CONCLUSION

Lean construction results from the application of a new form of production management to construction. Essential features of lean construction include a clear set of objectives for the delivery process, aimed at maximizing performance for the customer at the project level, concurrent design of product and process, and the application of production control throughout the life of the product from design to delivery. Significant research remains to complete the translation to construction of lean thinking.

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[3] Of course the contractor may be, but we cannot know unless the contractor is embedded in a principle based production system. By contrast we often see that behavior considered immoral is in fact a logical response to the failure in the underlying production system. Failure to provide labor to a project can be understood as evidence of bad upbringing.

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REFERENCIA DE INFORMACIÒN ADICIONAL

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NCT-S:	NATURE OF CONSTRUCTION TECHNOLOGY (SLIDES)
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