SUSTAINABLE CONSTRUCTION FOR THE FUTURE

Refereed Paper

BENCHMARKING SUSTAINABLE RESIDENTIAL DWELLINGS

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ABSTRACT

This paper will summarise the findings from a study that explored the link between dwelling design, or type, and energy efficiencies in sub-tropical climates. An increasing number of government and private sector development companies are initiating projects that aim to deliver enhanced environmental outcomes at both sub-divisional and dwelling levels. The study used AccuRate, a new thermal modelling tool developed by CSIRO that responds to the need to improve ventilation modelling. The study found that dwellings developed in conjunction with the Departments of Housing and Public Works have set the benchmark. It provides a snapshot of the energy efficiency of a range of dwelling types found in recent subdivisions. However, the trend toward increasing urban densities may reduce the likelihood that cooling breezes will be available to cool dwellings. The findings are relevant to regulators, designers and industry in all states interested in reducing the energy used to cool dwellings in summer.

Keywords: Sustainable, ventilation, energy-efficiency, density, benchmarking

1.0 BENCHMARKING SUSTAINABLE RESIDENTIAL DWELLINGS

Australia's pattern of residential development is resulting in urban sprawl and highlights the need for development to be more sustainable to avoid unnecessary demand on natural resources and to safeguard the environment for future generations. This becomes more apparent when we note that:

- Australia's per capita consumption of space (floor space, private and open space) energy and water rank among the highest in the world and continue to increase
- Australia's per capita waste is among the world's highest
- Australia's metropolitan planning and development strategies deliver poor environmental outcomes in energy production and consumption and CO_2 emissions, with rapid growth in transportation and resistance to distributed or solar energy in suburbs.

Queensland is currently Australia's fastest growing state, and:

- The estimated population of the region in 2004 was 2.65 million
- This is projected to increase to 5.3 million by 2026
- The population increase is an average of around 50,000 each year.

Much of the population growth is in SEQ region, which encompasses eighteen local governments, extending from Brisbane north to Noosa, south to the New South Wales border and west to Toowoomba. This region has:

- Experienced sustained population growth since the 1980s
- Is growing at an average of 55,000 persons each year
- Requires some 550,000 new dwellings to be constructed between 2004 and 2026.

1.1 RESIDENTIAL ENERGY USE

The use of energy in the dwelling is the largest source of greenhouse gas emissions from Australian households. The average household's energy use is responsible for about eight tonnes of carbon dioxide (CO2), the main greenhouse gas, per year (Reardon, 2001). Figure 1 shows the typical Australian breakdown of energy consumption within the dwelling and shows that space heating/cooling and water heating dominates the energy use profile. Reducing a dwellings need for such energy or seeking alternative renewable means of energy for these areas will greatly reduce Australia's overall environmental impact and greenhouse gas production.

Figure 1 Australian household energy use

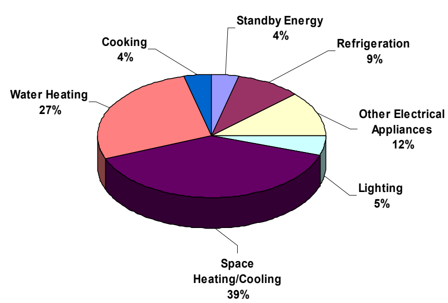
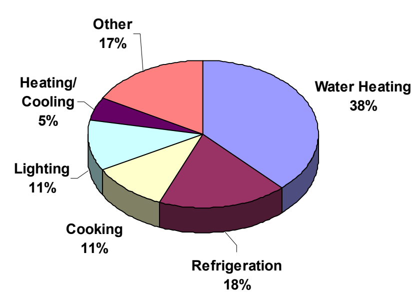


Figure 2 Queensland household energy use



Energy use in Queensland is quite different from the pattern for the rest of Australia. Figure 2 shows that in Queensland, the single biggest consumer of energy in the dwelling is hot water heating (Queensland Conservation Council 2004). Figure 2 also shows that heating and cooling energy accounts for only five per cent of the total, compared with 39 per cent as the Australian average (Figure 1). This difference is due to the temperate climate of Brisbane where the need for conditioned spaces is minimal. While the percentage of energy used to cool dwellings is small compared to the southern states, savings in this area are still important. In any event, this percentage is set to increase as Queenslanders install airconditioning at an increasing rate.

Figure 3 Air-conditioned households in Queensland

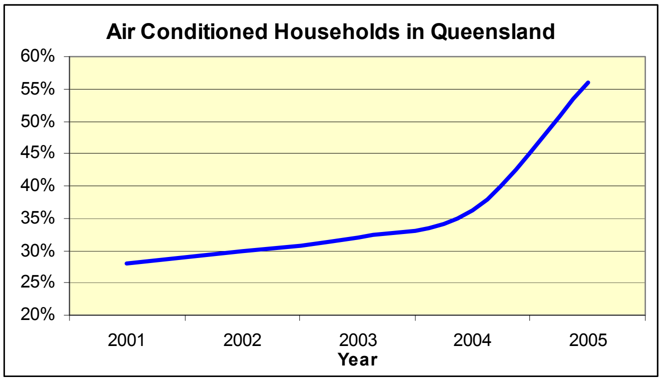


Figure 3 shows that in 2001, around 28 per cent of dwellings were airconditioned. By 2004, this figure had increased to 36 per cent and is expected to continue to increase to 56 per cent in 2005 (Mickel 2004).

This paper will summarise the findings from a study that explored the link between dwelling design, or type, and energy efficiencies in sub-tropical climates. The findings are particularly relevant to regulators, designers and industry in the warmer climate states of Queensland, Western Australian and the Northern Territory. The findings are also relevant to the cooler states as all dwellings have the potential to use energy to cool dwellings in summer.

1.2 THE CASE STUDY DWELLINGS

In September 2003, Queensland adopted the Building Code of Australia (BCA) energy efficiency provisions, which address house construction specifically, as this influences the amount of energy needed for heating and cooling. These provisions include requirements for new housing to achieve a minimum energy performance of 3.5 stars[1]. This minimum rating currently under review and is likely to increase to 5 stars (DLGP, 2004).

The study examined a range of dwellings types that commonly occur in new developments to provide a snapshot of the range of energy efficiencies in the aftermath of the introduction of these energy provisions. There are two broad categories, those designed for traditional 'cut and fill' lots and those designed for sloping lots;

- Slab on ground construction (Figure 4 to

[1] The present star band settings cover a range of 1 to 5 stars with 5 being the best and 1 representing the worst, or highest level of energy consumption

Figure 7)
- Elevated and pre-fabricated construction (to Figure 11).

A growing number of government and private sector bodies are initiating projects that aim to deliver enhanced environmental outcomes rather than continuing with a 'business as usual' approach. At the sub-divisional level, some developers engage sustainable principles in sub-divisional layouts and in construction, providing environmental plans and site analysis recommending layout for a home suited to each site (Ambrose, Mead et al., 2004)

At the dwelling design level, this approach to dwelling design is exemplified in dwellings developed in conjunction with the Departments of Housing and Public Works. These dwellings include Research House, Rockhampton and the Smart Homes at Springfield. These dwellings were selected for examination because they address the range of sub-divisional issues developers and designers contend with in SEQ, such as designing to address increasingly percentage of steep slopes and of small sites, as well as the complexities of designing to exclude excessive solar access and optimise natural ventilation (QDPW, 2003).

Figure 4 Case study 1 Research House, 220m², single storey blockwork on slab, metal roof,4 bedroom, 2 pedestal

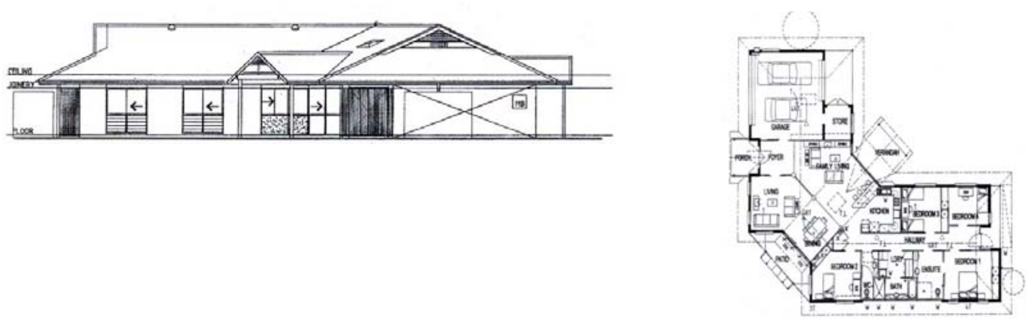


Figure 5 Case study 2 – 194m², brick veneer on slab, tiled roof, 4 bedroom, 2 pedestal

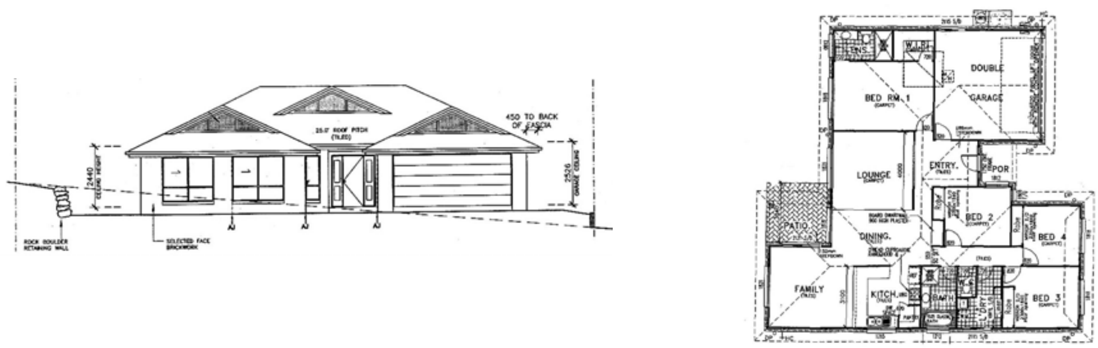


Figure 6 Case study 3 - 104m², brick veneer on slab, metal roof, no eaves on long axis, 3 bedroom, I pedestal

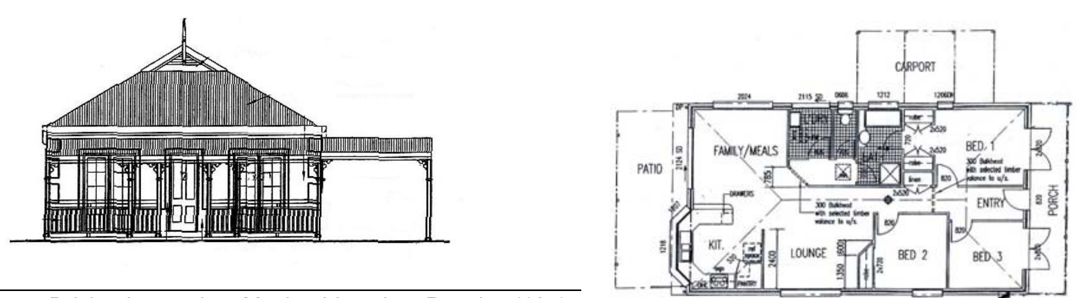


Figure 7 Case study 4 – 287m², two storey brick veneer on slab, metal roof, 4 bedroom, 3 pedestal

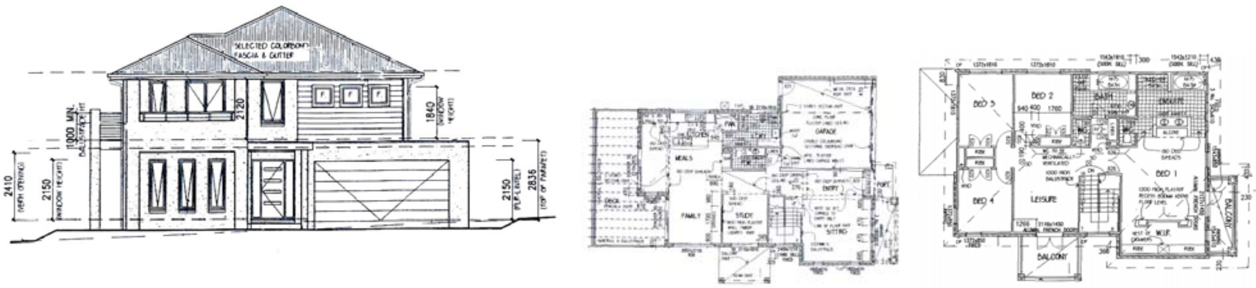


Figure 8 Case study 5 –Greensmart Home, 150m²single storey, elevated, clad, metal clad, 3 bedroom 2 pedestal

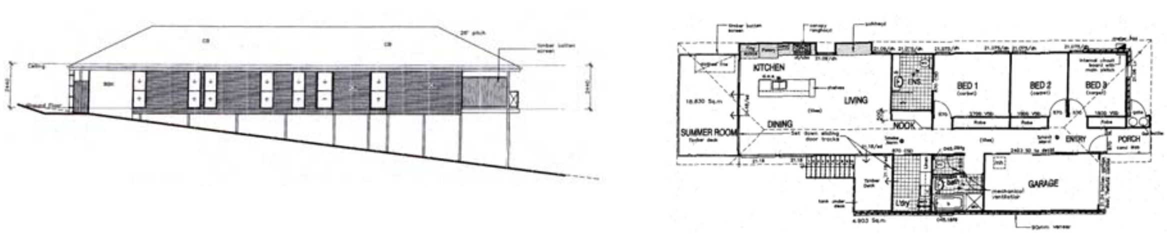
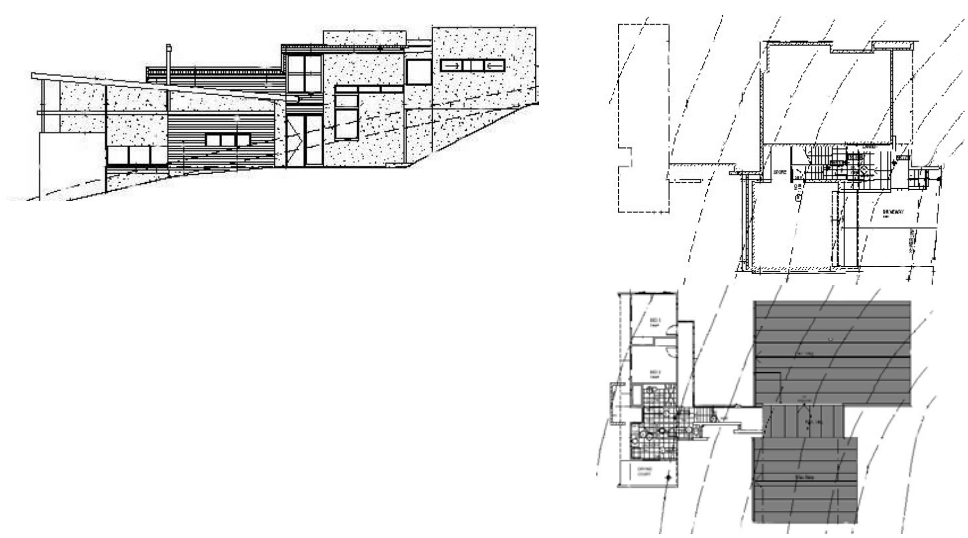


Figure 9 Case study 6 – 263m², split level, clad, metal roof, 3 bedroom, 2 pedestal



10 Case study 7 – prefabricated, 100m²single storey elevated, clad, 3 bedroom, 1 pedestal

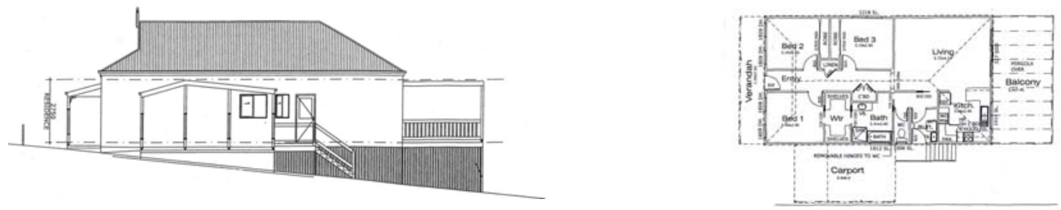
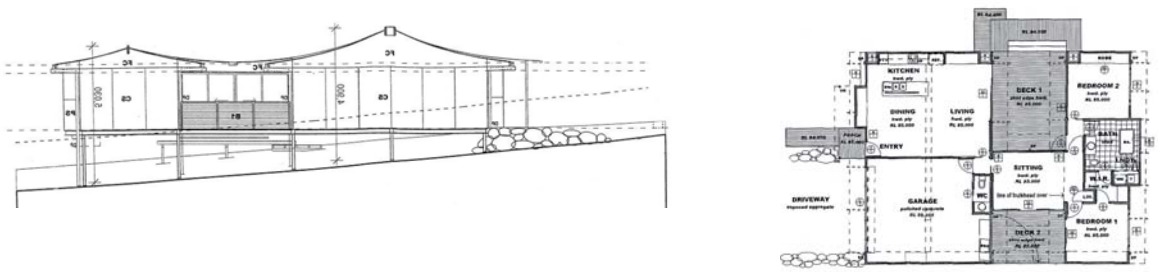


Figure 11 Case study 8 - 140m² single storey elevated, prefab, lightweight clad, metal roof, 2 bedroom, 1 pedestal



Further details of these dwellings can be obtained from the Industry Report (Miller and Ambrose, 2005). available online at http://www.construction-innovation.info/images/pdfs/SusSubdivsRTI_final.pdf.

1.3 ASSESSING ENERGY EFFICIENCY

Dwelling energy efficiency is expressed on a scale of 1 to 5 stars, with 5 being the most energy efficient. The star band settings are supplied by the Australian Greenhouse Office (AGO) and are derived from the annual total energy load, which is expressed in mega joules per metre squared per annum (MJ/M²/annum) as follows:

Table 1 Star band settings

0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
450+	<450	<360	<270	<180	<160	<140	<120	<100	<85	<70

A significant variation in annual total load could be considered as a variation that causes the star band score to alter by ±½ Star. At the time of this study, the band settings data was being reviewed by the AGO. As a result, this study will discuss the dwelling energy efficiency in terms of underlying MJ/m²/annum and not in terms of the star ratings.

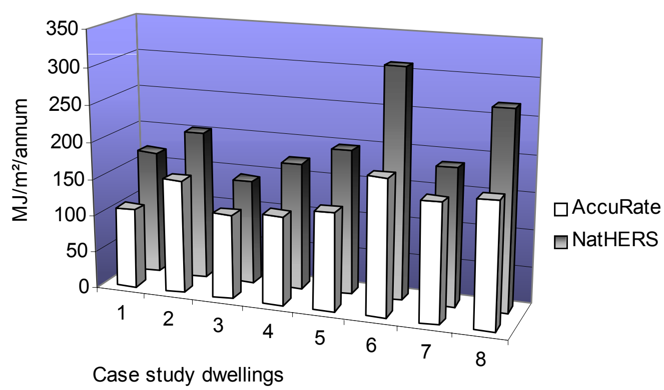
One of the drivers to improve the Nationwide House Energy Rating Scheme (NatHers) was the need to improve ventilation modelling and especially in tropical and sub-tropical climates (Commonwealth of Australia, 2004). In these climates zones, there has been concern that the current regulations, modelling and assessment tools do not address local conditions sufficiently, as evidenced by the following:

> Queensland, through intense lobbying by the Master Builders, introduced a variation to the BCA to better suit Queensland conditions relating to light weight construction and block construction *(QMBA, 2004)*

This study used AccuRate, the new thermal modelling tool developed by CSIRO. While the NatHERS ventilation model makes some provision for ventilation, it is far less detailed than AccuRate's ventilation model.

All the case study dwellings, including Research House, were modelled in AccuRate in the same climate zone to avoid variations in energy consumption due to climatic differences. Springfield, (Climate Zone 9), was selectedas a typical new subdivision. Springfield is an outer suburban Greenfield development of 2860 hectares located 23 kilometres from the Brisbane Central Business District (CBD), and expected to house some 60,000 residents by 2012. All the case study dwellings meet, or exceed, BCA 2003 DTS requirements in terms of their constructions, so the point of comparison lies between the case studies totals, as shown in Figure 12.

Figure 12 NatHERS and AccuRate - impact of improved ventilation modelling on energy efficiencies



The study found that the improved ventilation modelling resulted in a decrease of between 14 and 41 % in the annual total load between NatHERS and AccuRate. This is predominantly due to decreases in the energy used to cool the premises. As improved ventilation modelling is clearly indicated, the difference in energy efficiencies between the case study dwellings relates to the differences in the dwelling design and construction methods.

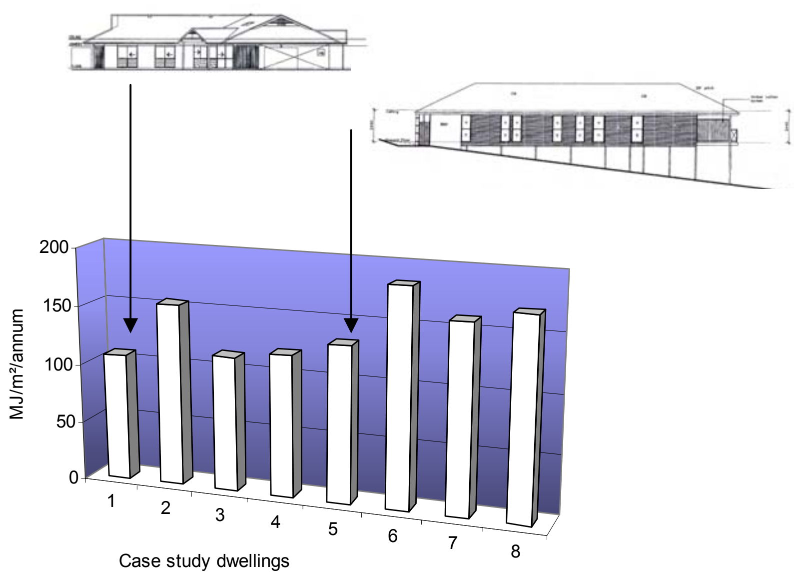
1.4 BENCHMARKING ENERGY EFFICIENCY

Early in the study that underpins this paper, industry informants noted that at present the energy efficiency requirements could be met simply through BCA deemed to satisfy (DTS) provisions. Informants also noted that there is no clear measure of how to achieve the necessary standard, or to meet increasing standards. Benchmarks are required so that industry could learn how to achieve a sustainable outcome without losing any competitive edge in the market (Mead and Wales, 2004). This is particularly important in Queensland, which has developed housing styles that differ from the more populous and cooler southern states.

Research House (case study 1, Figure 4) has set the benchmark for dwellings suited to the more traditional Greenfield 'cut and fill' slab lots and the Greensmart Home (case study 5,

Figure 8) has set the benchmark for the elevated dwellings suited to sloping sites, as shown in Figure 13. The annual loads for both these dwellings may be conservative. In case study 1, there are a number of materials and design options that could not be included in the modelling, while the final design for case study 5 included additional ventilation features that are not included in the modelling.

Figure 13 Range of energy efficiencies in new subdivisions



There is a marked variation in the range of annual total loads between the most efficient, case study 1 (107.7 MJ/M²/annum) and the least efficient, case study 6 (184.8 MJ/M²/annum) of the case study detached dwellings. While the impact of the variation is yet to be quantified in terms of star ratings, this range suggests that further design changes are required to optimise energy efficiency in new dwellings. It is timely to note that a survey of dwellings constructed in Victoria between 1990 and 1999 revealed that DTS provisions aimed at achieving a goal of 3 stars inadvertently permitted 1 star dwellings to be constructed (AGO, 1999b). Also, as the AGO notes:

> While there is overall compliance with mandatory requirements for thermal performance, it appears that the residential building industry does not always take advantage of simple or low cost design options for additional thermal efficiency (AGO, 1999b)

A number of issues arise from this snapshot of the energy efficiencies in new subdivisions:

- The results reflect the energy efficiencies of the post-BCA 2003 case study dwellings only and so do not reflect the energy consumption of the majority of the existing dwellings constructed pre-BCA 2003.
- the amount of flat land available for development in SEQ is rapidly diminishing and developers and designers are increasingly facing steep and complex sites that do not suit cut and fill techniques such as are required for slab construction
- The trend in future may be toward higher, rather than lower energy consumption.

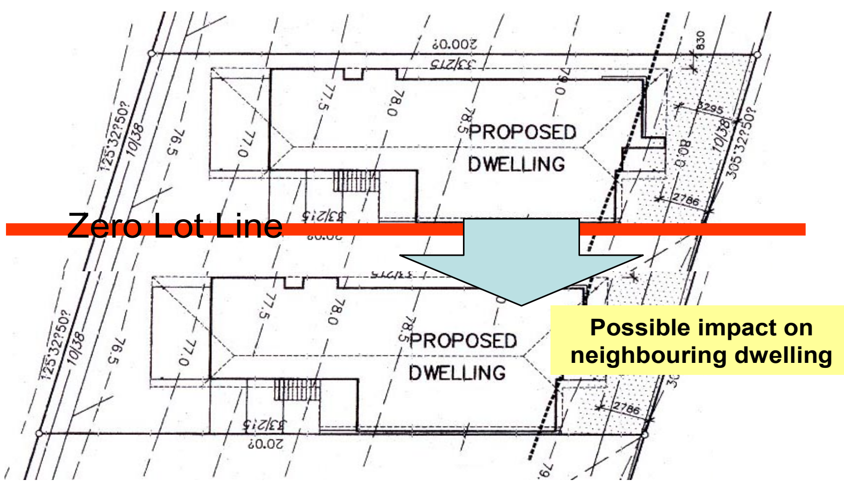
Both sub-division and dwelling designers need access to methodologies and tools to augment passive design principles and improve the thermal performance of residential dwellings as they contend with increasingly complex sites and regulations. However there is another factor that may lead to an increase in the energy required to cool residential dwellings, and that is the impact that increasing urban densities may have in reducing access to natural ventilation.

2.0 CHANGING RESIDENTIAL DEVELOPMENT PATTERNS

Australia's pattern of residential development will continue to change as suburban and urban densities increase and as the regulations governing energy efficiencies toughen. Regardless of how well designed a dwelling or subdivision may be designed, external conditions will change as the suburb matures. The most likely change is that over time, increasing suburban and urban densities (through additional structures or increasing vegetation) may shield a dwelling from access to natural ventilation. It will become increasingly important that dwelling energy efficiency be measured in terms of the dwellings context within a subdivision.

Examining one of the dwellings, case study 5, Figure 8, known to be located in close proximity to its neighbour, as shown in Figure 14, triggered an examination of the impact of increasing the external shielding for all the case study dwellings.

Figure 14 Impact of minimal boundary clearance on adjoining properties



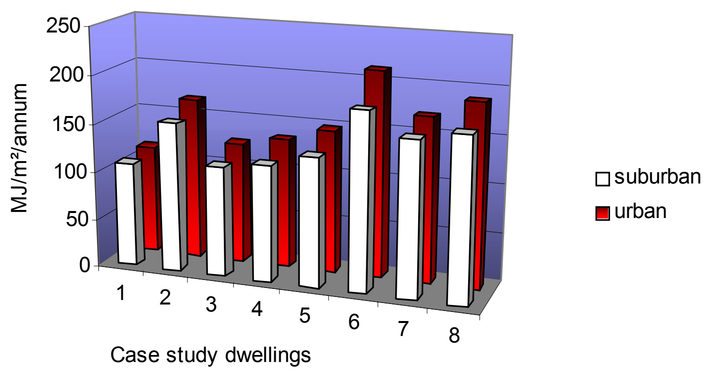
This examination was made possible because AccuRate, allows the external shielding factor to be selected from a range, which includes:

- None: no surrounding obstructions
- Light: a few surrounding obstructions (e.g. a house in the country)
- Moderate: obstructions typical of suburban housing
- Heavy: obstructions typical of inner-urban housing.

The results of the changing the external conditions by increasing the degree of external shielding, and reducing access to natural ventilation are shown in

Figure 15.

Figure 15 Impact of increased external shielding on energy efficiencies



This finding confirms and quantifies 'common knowledge' principles of orienting for ventilation. The variation in annual total loads is again important, ranging from 113.0 MJ/m²/annum (case study 1, Figure 4) to 212.9 MJ/m²/annum (case study 6, Figure 9). Because of the number of simulations involved, the worst-case combination of poor orientation and increased external shielding was not examined in detail for each of the case study dwellings. However, for case study 3 (Figure 6), which is one of the better performing dwellings, this worst-case scenario resulted in an increase in energy consumption, and a decrease in energy efficiency, of 40 MJ/m2/annum, or approximately 30 % above the optimum annual total load.

It is highly likely that in some instances a project home will be sited to suit a sub-divisional layout that is inappropriate for the dwellings design. 'Blank canvas' EER's displaying approximate star ratings throughout 360° of rotation and in a variety of urban and suburban settings, could easily be displayed on the plans as an added feature for the energy consumption conscious consumer. Importantly, if such information were readily, and reliably available throughout the design process, it would enable designers to test a range of ventilation and shading options as the design progresses, instead of forcing them to react to an inappropriate rating at the end of that process.

A number of points concerning future dwelling assessment processes arise from this discussion:

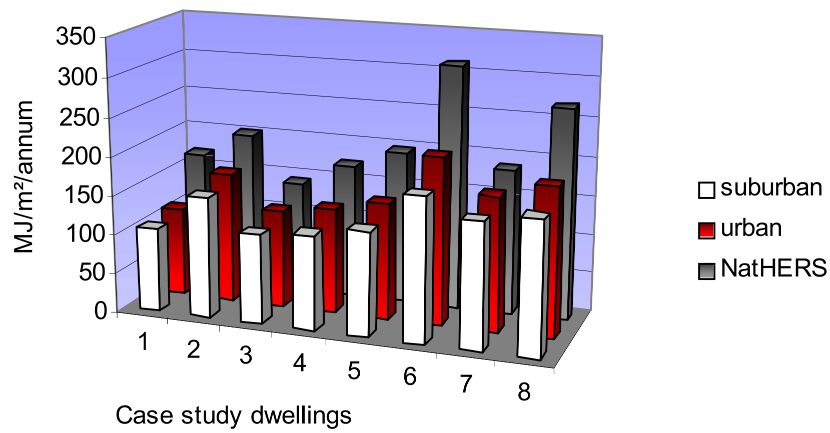
- Data on adjoining properties is rarely available at the time of rating the dwelling
- Assessors have to rely on their knowledge of the area in a paper based process
- In the absence of data on the surrounding dwellings, it would be reasonable for an assessor to assume that a suburban setting equates to a suburban selection
- Any reduction in energy loads may be sufficient to gain an additional half star if the original rating is close to one of the star band thresholds. This point is important if a dwelling is struggling to comply and as star ratings increase over time
- The shielding assumption needs to be disclosed in the ratings statement.

These are a function of the use of the programs and not of the programs' performance.

2.1 Measuring ongoing change in subdivisional residential patterns

As our suburbs change and suburban and urban densities increase, it is possible that the energy efficiency of dwellings may reduce and approach the levels indicated by the earlier NatHERS program, as shown in (Figure 16).

Figure 16 Possible impact of increasing urban densities on access to natural ventilation to cool residential dwellings



The impact of such growth and change over time has the potential to be captured through a process similar to that in use in the Australian Capital Territory (ACT), where dwelling energy efficiencies are re-assessed at point of sale.

In 1999, an AGO report into Australian Residential Building Sector Greenhouse Gas Emissions 1990-2010: noted that

> New residential dwellings account for approximately 20 % of the total housing stock. As a result some 80 % of the stock is outside the scope of this report *(AGO, 1999)*.

Also in 1999, the ACT sought to narrow this regulatory gap between existing and new stock. Since March of that year, the Energy Efficiency Ratings (Sale of Premises) Act 1997 requires the disclosure of an existing dwelling's energy rating in all sale advertisements for the premises, and provision by the vendor of an Energy Rating Report to purchasers prior to entering into a contract for sale. (ACT PLA, 2003a). According to the AGO,

> There would be some indirect market pressures if energy-efficient dwellings commanded a higher price; this is one objective of house energy rating schemes, but their influence on buyer or occupant behaviour is still unclear *(AGO, 1999)*

There is anecdotal evidence to suggest that the presence of energy efficiencies in property guides over the last few years, has heightened awareness of this issue among the owners of the 80 % of the residential market currently unaffected by increasing energy efficiency provisions. An ACT firm has been recording the price, location and energy rating of dwellings advertised for sale in the ACT over four years and has noted:

- A minor increase in value in 0 star rated dwellings, due to the impact of the aged inner-city housing stock which is valued more for the land on which it stands than for the nature of the houses themselves

- A bulge around the 2.5 star band representing the bulk of ACT housing
- A third bulge at 4 star driven by mandatory 4 star new dwellings
- A clear increase in value for 5 star rated dwellings
- A market preference for energy efficient dwellings (Energy Partners, 2003).

It would seem reasonable to assume that this trend could lead to a greater consumer awareness of energy efficiency and to increasing pressure on the accuracy of the modelling tools. Therefore, while the intent behind the ACT legislation was to extend energy efficiency provisions into the existing dwelling market, use of the latest generation of thermal tools at point of sale may also enable the ongoing assessment, examination and improvement of dwellings as suburbs and regulations continue to change.

3.0 CONCLUSIONS

This study has discussed a number of factors that need to be considered by regulators, developers, designers and industry in the journey toward creating, and maintaining energy efficient sustainable subdivisions. These include:

- The use of energy in the dwelling is the largest source of greenhouse gas emissions from Australian households
- Energy use in Queensland is quite different from the pattern for the rest of Australia
- The percentage of energy used to heat and cool dwellings is small compared to the southern states, but is set to increase air-conditioning is installed at an increasing rate
- Queensland adopted the BCA energy efficiency provisions in September 2003
- Dwelling energy efficiency is constrained by the sub-divisional layout
- The need to provide sub-divisional designers with a methodology to improve energy efficiencies
- Improved ventilation modelling in AccuRate resulted in a decrease in energy use of between 14 and 41 %
- The dwellings developed in conjunction with the Departments of Housing and Public Works have set the benchmark for slab on ground and elevated dwellings
- A snapshot of EERs in a range of dwellings that commonly occur in new subdivisions revealed a marked variation between the best (107 MJ/m^2/annum) and worst (184.8 MJ/m^2/annum) performing dwellings suggesting that further design changes are necessary to optimize energy efficiencies
- Energy efficiencies achieved by these case study dwellings do not reflect energy patterns in the 80 % of the housing stock that pre-dates the current regulations
- Increasing urban densities have the potential to restrict or block access to natural ventilation
- The need to provide designers with a tool to augment passive design principles and improve the thermal performance of residential dwellings
- 'Blank canvas' EER's displaying approximate star ratings could be displayed on the plans as an added feature for the energy consumption conscious consumer
- That current regulations are likely to increase over time, leading to generations of energy efficiencies throughout the suburbs
- Point of sale assessment allows the impact of energy efficiency to extend into the existing dwelling market
- Use of the latest generation of thermal tools at point of sale may enable the ratings process to capture, examine and design for, the impact of ongoing change as suburbs and regulations change.

These are critical factors as Queensland moves to implementing a whole of government Sustainable Housing Policy and as Australia moves toward increasing energy efficiencies for new residential dwellings and toward extending energy efficiency provisions into the existing dwelling market.

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INDUSTRY DEVELOPMENT

Case Study

INNOVATION THROUGH HARNESSING CONSTRUCTIVE IDEAS OF CONSTRUCTION PERSONNEL

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ABSTRACT

The construction Industry is one of the significant industries to a country. Any improvement in productivity in the industry can have a positive impact on the general economy. Innovation can be used as a leverage to improve the productivity in the construction industry. A form of corporate innovation, which is often forgotten by many, is harnessing innovative ideas of employees in organisations. This form of innovation can be used effectively to improve the performance of construction organisations.

This paper will examine the importance of this form of innovation and the reasons why it is not popular in organisations. The strategies and systems that can be used to capture, develop and utilise employee ideas in construction organisations are identified and discussed. One of the poorly performing sectors of corporate innovation is the public sector. Promoting corporate innovation in public sector construction organisations is given particular consideration in the paper.

Keywords: Corporate innovation, technological innovation, corporate culture, recognition and reward, suggestions systems.

1.0 INTRODUCTION

The construction industry is a crucial driver of economic activity in Australia. In 2002-03, construction was Australia's fourth largest industry contributing 6.3% of GDP. Production of the construction industry measured by GVD (Gross Value Added) was $ 45,977 million in the same year (Australian Bureau of Statistics, 2005). The industry employed over 7% of the workforce during the year, employing about 730,000 people (My Future Fact Sheet, 2005).

The construction industry consists of those businesses engaged mainly in the construction of residential and non-residential buildings, engineering structures and related trade services (Australian Bureau of Statistics, 2005). Some writers refer to this industry as building and construction industry. However, in this paper, the word construction industry refers to both building and construction industry.

Smarter construction through innovation can improve the productivity in the industry. Peter Scuderi of CRC for Construction Innovation, Australia has calculated that a modest productivity gain of 1 % sustained from 2005 to 2020 would add about $12 billion to the GDP for Australia (Scuderi P, 2004).

Corporate innovation, which can significantly contribute to productivity gains, is predominantly harnessing creative and innovative ideas of employees for the betterment of organisations. If constructive ideas of construction people can be captured and utilised, Australian construction industry can significantly improve its productivity. Unfortunately not many construction organisations use this effective tool to improve performance. Therefore, there is a need to discuss the importance of this vital form of innovation.

2.0 INNOVATION AND HARNESSING IDEAS

2.1 INNOVATION AND CONSTRUCTION INDUSTRY

The prosperity of any economy depends on its productivity. Innovation contributes to higher productivity. In the absence of sustained innovation, the rate of growth in labour-constrained economies will ultimately fall to zero. Innovation can drive productivity improvement across all industrial sectors (Gans J, 2003:8).

Promoting innovation is particularly useful to engineering organisations involved in the construction industry as it will help to lower construction costs and improve construction performance (Manley, 2003:55). The survey conducted by the Australian Construction Industry Forum shows that innovation has a positive impact on project outcomes and high innovators are much more successful than low innovators at expanding market share and developing new markets (Australian Construction Industry Forum, 2002: 29). In the report, "The Chance to Change", Australia's Chief Scientist referred to innovation as the only way forward for Australia and identified it as the key to competitiveness, employment growth and social wellbeing. (Batterham, 2000).

There is 'much room for improvement' for the construction industry in Australia in the area of innovation. The Australian building and construction industry is experiencing considerable lower returns (cost savings, increased turnover) from innovation than world averages. Even high innovators in Australia are experiencing lower returns than international averages (Australian Construction Industry Forum, 2002: 49). The survey conducted by the Australian Construction Industry Forum shows that 48% of the respondents from organisations in the building and construction industry surveyed indicated that their organisations had no measure of innovation, either qualitative or quantitative (Australian Construction Industry Forum, 2002: 29).

2.2 WHAT IS INNOVATION?

Invention is the result of creative thinking that leads to the creation of a new technology or process. Innovation is the application of the new technology or process to a new product, service, or production or management process (Baker C., 2001:188). Innovation is the practical application of imagination. During the innovation process, an enquiring, curious and imaginative mind gathers new information, creates new knowledge and develops new perspectives, perceptions and possibilities that lead to new ideas (Baker C., 2001:13). Innovation involves many aspects such as:

- creating or generating new activities, products, processes and services;
- seeing things from a different perspective;
- moving outside existing paradigms;
- improving existing processes and functions;
- disseminating new activities or ideas; and
- adopting things that have been successfully tried elsewhere.

Innovation can be divided into technological and corporate (enterprise) innovation. Technological innovation is the invention of new technology and the development and introduction into the market place of products, processes, or services based on the new technology (Frederick, B 1998:3). Corporate innovation is to use innovation by whole organisations to achieve benefits. Harnessing employee ideas constitutes a major part of corporate innovation. Therefore, the first involves the development of new technology, whereas the latter encompasses innovation as a culture that permeates organisations.

While technological innovation is important, **the contribution to an enterprise resulting from a truly innovative culture is at least equivalent to the contribution from technological innovation** (Barker, C., 2001:23) [Emphasis added]. Governments and other entities mostly support technological innovation as it is easier to see and measure its results. Corporate innovation has not received its due place in many parts of the world, especially in Australia.

2.3 WHY INNOVATION IS NOT GIVEN ITS DUE PLACE IN ORGANISATIONS?

Writing to the 'The Futurist' magazine, the author of the book titled 'Driving Growth through innovation: How Leading firms are transforming their futures', Robert Trucker says "while the world has changed drastically and organisations pride themselves for having a process for every thing, the process of innovation remains ad hoc, unsystematic, piecemeal, seat of the pants, and, … heavily dependent on luck" (Tucker R. B., 2003).

There are many reasons why most organisations are less innovative. In his book 'Innovation and imagination at work', Barker says: "The main reasons why companies fail to be more innovative are:

- they falsely believe they are more innovative;
- managers get too busy in the day-to-day issues to focus on innovation (working in the business and not on the business);
- there is insufficient drive from the top of the organisation to prioritise innovation;
- staff are not sufficiently motivated to provide creative ideas;
- there is lack of goal congruence between senior management and staff;
- organisational and poor communication limit (or even suppress) innovation; and
- the culture of the organisation is not one which encourages innovation".

(Barker, C., 2001:19).

As compared to the private sector, public sector organisations are not performing well in corporate innovation. Karen Manley of the Queensland University of Technology, Australia points out that "the public sector's capacity to benefit from robust innovation appears to be currently under-utilised, both in Australia and world-wide" (Manley K., personal communication). Lack of profit motivation and fear of failure are two major reasons for this undesirable situation.

3.0 HARNESSING EMPLOYEE IDEAS

3.1 IDEA HARNESSING AND ITS BENEFITS

Ideas harnessing systems or suggestion systems are not new. They have been in operation for over hundred years. The concept was first recorded in Japan in 1721 with the then Shogun offering rewards for ideas (Beddows A., 2001). The first suggestion system was put into operation in 1880 at the Scottish shipbuilder William Denny and Brothers (Robinson A.G, 1997: 60). Today, idea harvesting systems have become a powerful, energising force for corporate creativity for leading-edge organisations.

Harnessing of creative and innovative ideas leads to innovative activities beneficial to employees and to enterprises. Enterprises receive a number of benefits from innovative activities including efficiency and revenue gains, service improvements, employee satisfaction, and acceptance of leadership status by other organisations and improved credibility. As organisations build innovative cultures, they also augment and develop trust, loyalty and commitment among workers, and enhance the job satisfaction of both the leaders and the workers (Baker C., 2001:xi). A recent survey of 60 organisations in UK, representing nearly one million employees showed first year savings of £89 million by harnessing employee ideas. Notably amongst these was the Ministry of Defence with £21 million savings (Beddows A., 2001).

Contributing in innovative ideas is also beneficial to individual employees as they could receive recognition, promotional and other benefits in enterprises. Highly successful innovative ideas contribute to high financial gains for some employees, especially who work for the private sector.

3.2 SYSTEMATIC APPROACH TO HARNESSING IDEAS

A systematic approach is needed for an organisation to harness employee ideas. Such an approach generally includes an idea generation and capturing system and a conducive environment to encourage and support innovative activities. An idea generation and capturing system requires the following for its success:

- a panel or a network (for a large organisation) of persons to assess ideas;
- a panel to accept or reject ideas; and
- identified personnel to develop accepted ideas.

Web-based systems using sophisticated software programs and themed campaigns are two types of idea generation and capturing systems generally used.

3.3 IDEA GENERATION AND CAPTURING

In place of the 'suggestion box' used in the past, today's organisations use web-based systems for idea capturing using sophisticated software programs that acknowledge and track ideas and subsequent activities. Employees are encouraged to submit ideas directly into the system.

Some organisations encourage employees to submit ideas without giving their identities. This is in the belief that the identification of the suggester may allow the evaluator to form pre-judgments. Whether or not a suggestion is selected for further consideration, each suggestion is acknowledged. If a suggestion is not selected for further consideration, reasons for the same are given.

Some organisations require the preparation of a business case by the suggester for further consideration. This will allow the suggester to look at the idea in a broader organisational perspective and see its relevance to the organisation's business plan. Trained officers are available to assist suggesters to prepare the business case. At the time of preparing the business case, some suggesters withdraw their ideas, if convinced that the ideas are not compatible with the organisation's overall plan.

Another way of idea generation and capturing is the use of themed campaigns. These are also called 'Innovation Challenges'. They are one-off competitions for employees to forward their ideas for a management-chosen topic and the employee with the best idea is recognised and rewarded. Selection of the best idea is generally by a specially appointed panel. The topics for these challenges could involve the following:

- problems faced by the organisation where solutions are not easy to find;
- problems faced by the organisation where solutions require grass-root ideas; and
- organisational issues which require better understanding by the employees.

An example of a 'challenge' for a construction organisation is 'how to improve the construction quality?'

Both idea generation and capturing systems mentioned above require considerable publicity to take the message across to all employees in the organisation.

3.4 IDEA ASSESSMENT, DEVELOPMENT, IMPLEMENTATION AND COMMERCIALISATION

Idea assessment is made by at least one person (three persons preferable) knowledgeable on the subject area and trained on idea evaluation. Independent evaluation reports need to be prepared by these idea evaluators without consulting each other. In large organisations where a large number of ideas is expected, the assessment is made by a selected number of 'innovation leaders' who are trained to do this work.

Evaluator reports are generally forwarded to a special committee to take decisions on the idea. Often this committee consists of senior officers of the organisation and a few external experts. If the idea is selected for further consideration, an implementation team is formed. Often the suggester is selected as a member of this team (if not the leader) and required facilities are given to develop the idea further. If an idea warrants commercialisation, a separate company would be formed with the suggester appointed as an executive.

4.0 CONDUCIVE ENVIRONMENT FOR HARNESSING IDEAS

4.1 CONDUCIVE ENVIRONMENT AND THE ROLE OF TOP MANAGEMENT

Without a conducive environment, innovation will not flourish in an organisation and harnessing innovative ideas will be difficult. An environment conducive to harnessing employee ideas include:

- corporate culture to encourage and support innovation;
- encouragement and recognition of innovators and innovations;
- provision of facilities such as funding, training and mentoring; and
- establishment of a dedicated unit to handle all innovative activities.

It is not possible to have an environment conducive to innovation without the top management commitment. In order to promote innovation within their organisations, top management should focus on the following:

- empowerment of human resources;
- robust incentives to innovate;
- tactics to overcome obstacles to innovation; and
- building support networks, internally and externally.

The top management not only needs to support innovative activities, but also visibly demonstrate their commitment. Actions to encourage and support innovative activities may include personally recognising and rewarding innovators and innovations and emphasising the importance of innovations when they make presentations and issue personal messages to employees. There are many CEOs in high performing companies who invite successful innovators for lunch as a way of recognising them. Innovation often results in failures and mistakes. Accepting mistakes in the process of innovation should be part of the culture and senior managers should provide leadership by admitting their own mistakes in public.

4.2 CORPORATE CULTURE

An organisation with a culture oriented to facilitate innovation has distinguished characteristics including the following:

- trust of employees with a degree of freedom of thought and action to act in the direction of organisational goals;
- encouragement for the development and exploration of ideas;
- understanding and a belief of management that creativity, imagination and innovation are intrinsic to their roles;
- toleration of mistakes if done in the process on innovation;
- recognition, encouragement and support from all levels of employees towards innovative activities;
- high level of knowledge flow within the organisation;
- effective knowledge content management;
- availability of networking facilities within and outside the organisation; and
- strong relationships with clients and stakeholders.

4.3 RECOGNITION AND AWARDS

People will not innovate unless they get some reward, either financial or motivational. Private organisations generally provide monetary rewards for successful ideas. However, those organisations with small or non-existent budgets resort to awards that are more imaginative. These cost little, but have a high-perceived value to the recipient. They can include lunch with the CEO or providing car parking facility. Inexpensive ‘give-aways’ such as pens, mugs, diaries, calendars and other items of desk stationary are also being used by some organisations as rewards. They have a double effect of saying a ‘cheerful thank you’ to the recipient and keeping the innovation program in public view. Organisations also use some forms of point systems to reward ideas and the points can be accrued and later exchanged to some form of monetary value for store vouchers or gifts from catalogue. Rewards also can be in the form of company shares, promotions and leadership positions.

Providing monitory rewards is often difficult for public organisations, which generally use recognition and publicity as rewards. Announcing the winner in public alone is a satisfactory reward for many innovators. Organisations use internal publicity to publicise the names and photos of those with adopted ideas. Many organisations have ‘excellence award ceremonies’ annually to recognise and reward employees engaged in innovative activities. These are highly publicized events with top management participation. When rewarding best ideas from employees, it is also advisable to recognise ‘implementers’ of ideas. Implementers play a significant role in successful innovations and therefore, need encouragement and recognition.

The best ideas that go into commercialising phase could earn the suggester a substantial financial gain. Many organisations establish new ventures for commercialising ideas with suggesters given high positions to enable them to receive substantial financial gains.

4.4 TRAINING AND OTHER FACILITIES

It is necessary that all who involve in innovation related work are given training. Intensive training is required for those driving innovation related programmes and those who act as innovation leaders and idea evaluators. It is also preferable that at least a section of employees is given general training to understand the importance of promoting innovation in organisations. Depending on the persons to be trained, training may cover areas such as the importance of promoting innovation, how to look outside existing paradigms, problem solving and creative thinking, how to become involved in innovative activities, how to promote innovation and associated values and behaviours and how to evaluate innovative ideas. Innovative organisations also establish mentoring networks to assist innovative thinkers.

It is difficult to manage innovation without a dedicated unit to coordinate and implement innovative activities, unless the organisation is very small. Organisations leading in innovation generally have dedicated units to implement innovation programmes. These units are often established directly under the CEO, with a high profile position as the head of the unit to ensure its prominence in the organisation and the direct involvement of the CEO. The unit is allocated with necessary funding to undertake required activities.

5.0 CONCLUSIONS

The construction industry is one of the significant industries to a country. Any improvement in productivity in this industry can have a positive impact on the general economy. Innovation can be used as a leverage to improve productivity in the construction industry.

One of the most important areas of innovation, which is often forgotten by many, is corporate innovation. Corporate innovation is predominantly harnessing creative and innovative ideas of employees for the betterment of organisations. If constructive ideas of construction people can be harvested and utilised, Australian construction industry can significantly improve its productivity. Therefore, it is necessary to emphasise the importance of harnessing employee ideas to the construction industry.

Harnessing creative and innovative ideas of employees needs considerable efforts and resources. The systems that can be used to capture, develop and utilise employee ideas in construction organisations were identified and discussed in the paper. One of the requirements highlighted was having an innovative culture, which requires strong commitment from the top management. There is less enthusiasm for harnessing employee ideas in the public sector construction organisations, especially in Australia, which needs to be addressed to improve performance.

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INDUSTRY DEVELOPMENT

Case Study

NEW COMPLIANCE DATA MANAGEMENT SERVICE TO IMPROVE IMPLEMENTATION OF QUALITY ASSURANCE IN THE BUILDING AND CONSTRUCTION INDUSTRY

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ABSTRACT

This paper describes how the innovative use of IT is transforming the way people view quality assurance (QA) within the building and construction industry.

A new service, the Compliance Data Management Service (CDMS), is providing an effective solution for implementing QA at the project work face. The CDMS provides the framework for enabling every checker of work to take responsibility and accountability for the quality of his/her work, through the provision of objective evidence at the time compliance with requirements is confirmed.

For the first time project managers have access to real time information for monitoring project quality thanks to the use of the Internet and other proven Information Technologies.

The impact of the CDMS on the building and construction industry will be profound. From the current position of a lack of confidence in QA as practiced, QA will become a key project driver.

Keywords: **quality assurance, construction, compliance, Compliance Data Management Service.**

1 WHAT? NOT ANOTHER PAPER ON QUALITY ASSURANCE?

Quality Assurance[1] (QA) has been a part of the Australian building and construction industry landscape for the better part of 15 years. Yet, even after 15 years, the effective implementation of quality assurance practices across the industry is less than ideal. Why is this so? Why is it so hard for the construction industry to embed quality assurance into the fabric of its work practices? Is QA just another management fad that has had its day?

The answering of these questions has led to the development of an innovative service by an ACT based company (ABE Services Pty Ltd) that provides the corner stone for the effective implementation of quality assurance across the construction industry.

The Compliance Data Management Service (CDMS) moulds a range of existing Information Technologies (IT) into a service that delivers compliance data directly to project personnel at the workface, and also provides real time records of the status of project verification activities.

This paper explores the issues associated with implementing an effective quality assurance program, which has lead to the development of the CMDS.

2 A BRIEF HISTORY OF QA IN THE CONSTRUCTION INDUSTRY

The Australian building and construction industry started to explore quality assurance from about the mid 1980's when sectors of the power industry started experimenting with the specifying of quality assurance requirements in contract documentation. The objective of these contractual requirements was to change the culture of the industry where the responsibility for quality control was, in practical terms, with the customer through customer inspection and approval of completed works.

Australian Standard (AS) 2990 "Quality Systems for Engineering and Construction Projects" was developed to:

- "To provide a customer with assurance that the required quality of product and service will be in accordance with contractual requirements, and
- To place on the contractor the responsibility for achieving the required quality and then demonstrating that it had been provided".

[1] Quality Assurance - All those planned or systematic actions necessary to provide adequate confidence that a product or service is of the type and quality needed and expected by the customer.

In 1990 the industry came together under the “No Disputes Forum[2]” in response to escalating contract disputation and poor quality project outcomes. A key initiative of the “No Disputes Forum was the formalising of quality assurance as a fundamental customer requirement, allowing the customer to stand back from the traditional hands on inspection/approval process.

The move from inspection to quality assurance was a seismic change for the industry and required a major shift in attitude and culture to implement.

AS2990 was eventually replaced by the international ISO 9000 series of quality system standards. Quality assurance is now a fundamental requirement in all commercial construction industry contracts.

3 CURRENT STATE OF QA

On the basis of 15 years experience quality assurance should now be second nature to the industry. Reasonable statement? Yes, but across the industry the implementation of effective quality assurance practices is patchy.

Major commercial building and construction companies have implemented formal quality systems. These companies have been driven over the years by customers through contractual requirements and selective tendering processes to implement certified quality systems. By and large the implementation of quality systems by major companies for their own processes is good.

Yet below this top tier of major contractors many subcontractors and trade contractors have not effectively implemented quality systems. The result is that the head contractors may need to extend their quality systems to embrace the subcontractors and trade contractors. The result? The head contractors have taken on the responsibility for quality control for their subcontractors and trade contractors. In other words the culture of quality assurance has really only moved down one layer in the construction delivery chain and the coverage of the lower layers may be not that effective.

Why has this occurred? Well one needs to know the structure and nature of the construction industry.

4 KNOW THE INDUSTRY

The Australian construction industry[3] is large. At the end of June 2003, there were 339,982 construction businesses operating in Australia employing 716,200 persons. Most of these businesses (79.2%) and most of the employment (73.2%) were in trade services.

In the non-residential and non-building construction sectors there were 22,553 businesses employing 106,400 persons (14.9% of total construction employment) or an average of 4.7 persons per business.

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[2] The No Disputes Forum comprised all building and construction industry employer associations (such as the Master Builders Association, Association of Consulting Engineers Australia, Royal Australian Institute of Architects, etc) and the National Public Works Council (NPWC) group of Commonwealth/State public sector construction organisations. In 1997 the NPWC became the APCC (Australian Procurement and Construction Council).

[3] From the Australian Bureau of Statistics, AusStats series 8772.0 - Private Sector Construction Industry Survey – 2002-03, and 1996-97.

Trade services businesses had the largest proportion of employees (66.4%), followed by non-residential and non-building (21.5%) and residential (12.1%). Most of the working proprietors/partners (84.1%) were found in trade services.

Small businesses (those with income less than $100,000) accounted for a large proportion (72% or 199,000 persons) of all working proprietors/partners, but only 6.2% (27,400) of all employees.

The 1997 statistics of construction industry employment more clearly illustrates the structure of industry employment for the then 194, 300 businesses:

- 182,000 businesses had 0 to 5 employees (or 93.7%);
- 11,100 businesses had 5-20 employees (or 5.7%); and only
- 1,200 businesses had over 20 employees (or 0.6%).

Based on these statistics and observations by the authors a number of conclusions can be drawn about the workforce:

- The industry has a significant trade base operating in small and micro businesses,
- People with a trade background tend to be ‘doers’ – more comfortable using their hands,
- Paperwork is tolerated, not embraced. Paperwork is not their business therefore it tends to be the last thing done in a workday, if done at all,
- Paperwork associated with quality assurance is seen as just another administrative burden, impacting on ‘getting the job done’,
- Filing of quality assurance records (if produced) is less than, and
- The administrative effort to implement and maintain a quality system is too much except for the larger companies that can afford to employ someone to do it.

It is no wonder small business has not embraced quality assurance and associated quality systems. Within the residential sector, where it could be argued that quality assurance is more important than the commercial sector (as there is generally no ‘expert’ oversighting residential construction as is the case with commercial construction), quality assurance is not evident at all!

This has lead to a continuing lack of confidence in quality assurance as it is currently practiced.

So to the problem – How to make quality assurance meaningful and effective for the majority of industry participants?

5 CHARACTERISTICS OF AN EFFECTIVE QA SOLUTION

Recognising the demographics of the industry, a required solution needs to:

- Minimise paperwork,
- Minimise filing,
- Assist the users implement quality assurance processes, not hinder them with burdensome administrative tasks,
- Be able to be effectively implemented by small business,
- Minimise additional administrative resources,
- Enable ready communication of quality assurance information to other parties,

- Facilitate effective interaction between project participants, and
- Have an acceptable cost profile.

6 THE ROLE OF 'IT' IN ADDRESSING THE SOLUTION

Over the past five years or so Information Technology (IT) has been undergoing a revolution as various technologies mature and begin to converge. By way of example mobile phones have become fundamental to communicating within the industry. The mobile phone has made small businessmen and tradesmen accessible anywhere, anytime. The Internet has matured to the point that the majority of written project communications is now done through email. Mobile devices such as the Blackberry™ merge telecommunications and the Internet to bring email to the user anywhere, and handheld devices enable information to be stored electronically.

Many larger companies have also developed IT solutions to address specific work needs, but these tend to be costly and generally difficult to modify for other businesses.

In developing a quality assurance solution, ABE Services has been able to bring together IT professionals with building and construction industry quality professionals to grow a solution merging a number of information technologies that addresses the 'characteristics of a solution' discussed above.

In developing a solution the overriding requirement was that the solution could be used by the trades sector within the industry.

7 THE SOLUTION – THE CDMS, A FOCUS ON SIMPLICITY

The Compliance Data Management Service (CDMS) is a web-based service, which addresses the identified 'characteristics of a solution'. The services utilises Palm Pilot™ Personal Digital Assistants (PDA's), to provide mobility at the workface, connecting as required via the Internet to a central database and application. Figure 1 illustrates the system basics.

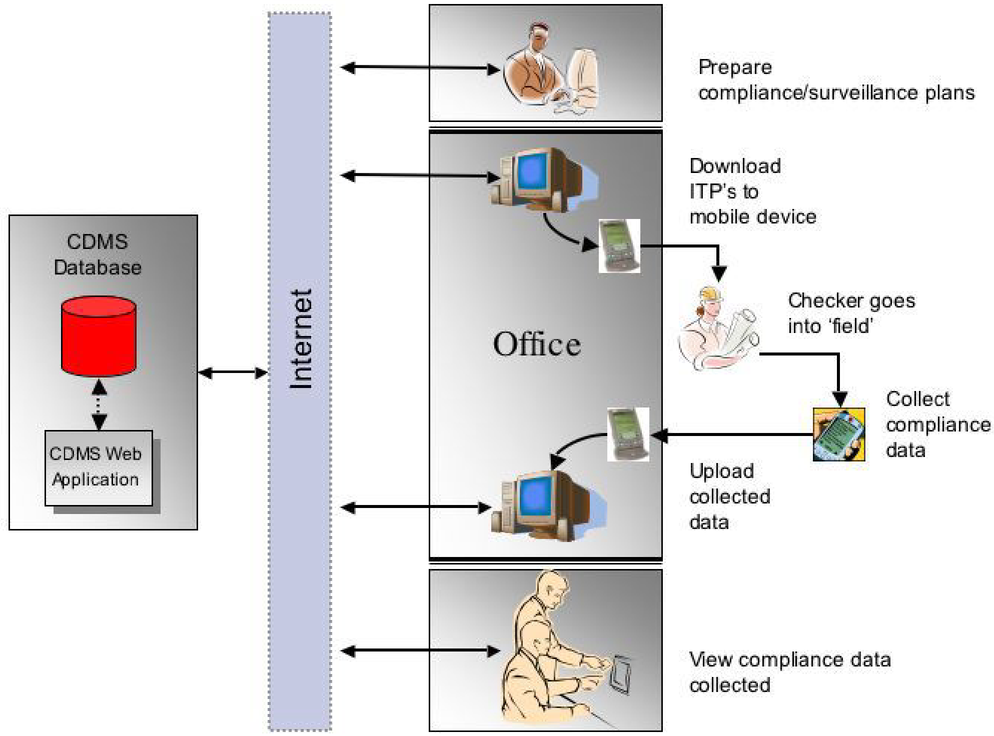

Figure 1- Core CDMS workflows

The service supports a number of workflow processes:

- Preparation of industry standard Inspection and Test Plans[4] (ITP) including the ability to manage those ITPs – under preparation, approved for use, halted, deemed complete, etc,
- Transferring the ITP verification points from the web developed ITP to the PDA via a connection to the Internet,
- Completing the verification activities on the PDA,
- Transferring the marked off verification points from the PDA back to the central database via a connection to the Internet,
- The raising, management and closure of Actions (or non-conformances) on the PDA,
- Reviewing the results of synchronising the PDA with the database via a web browser or a suite of PDF reports.

Figure 2 illustrates the PDA workflows.

[4] Inspection and Test Plans are formal plans setting out what the supplier (builder, contractor, subcontractor, trade contractor, and manufacturer) will inspect and test for a particular work activity. The Inspection and Test Plan had its genesis in Australian Standard (AS) 2990. The Inspection and Test Plan has become standard practice within the industry.

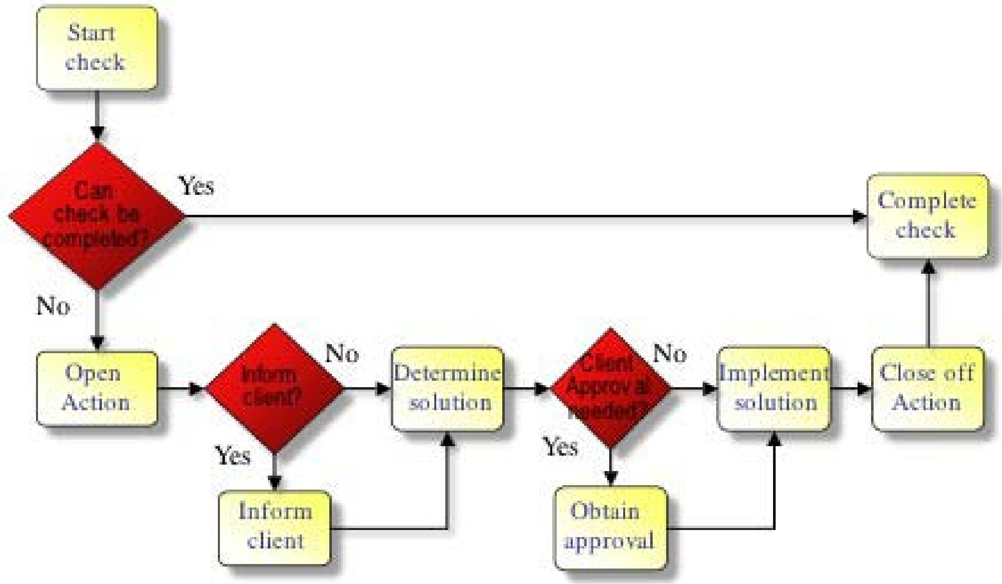

Figure 2 - PDA workflows

The following table sets out how the CDMS meets the identified solution characteristics discussed this paper:

Ref.	Characteristic	Feature/Benefit
1	Minimise paperwork	The CDMS delivers the relevant ITPs electronically to the specified 'checker'[5]via the PDA. Data arising from completing the checks on the PDA are electronically delivered back to the central database by regular synchronising. Actions can be raised electronically on the PDA, and notes can be jotted against verification points or Actions electronically on the PDA.
2	Minimise filing	All information collected via the PDA is stored on the database and collated by project. Retrieval of data is by project and collated reports are provided in PFD format.
3	Assist the users implement quality assurance processes, not hinder them with	The ITPs provide the job planning tools, and the completion of the verification points on the PDA by 'ticking off' ensures the implementation of those plans. The ability to instantly raise Actions electronically by the checker at the workface means

[5] The person allocated the responsibility to sign off the verification points an ITP.

Ref.	Characteristic	Feature/Benefit
	burdensome administrative tasks	problems should not be glossed over. The data so gathered also provides the foundation of the quality improvement process.
4	Be able to be effectively implemented by small business	The system has been developed to provide small business with a range of ITP templates that can be used without modification or minimal modification, thus relieving the user from having to develop ITPs from scratch. The user also has the ability to copy ITPs from one project to the next if the nature of the users work is repetitive (which is the generally the case with small businesses). The PDA application is intuitive and easy to use.
5	Does not require additional administrative resources	No additional resources are needed to administer the CDMS. Refer to Ref. 4 of this table - re simplicity of ITP development. Existing users of the CDMS develop their own ITPs for a project, thanks to the templates. This has improved the quality of ITPs and the speed of development.
6	Enables ready communication of quality assurance information to other parties	The project PDF reports (refer Figure 3) can be printed off daily and sent by email to other project participants. Alternatively, access can be given to clients and others to enable them to view progress or print off the PDF reports.
7	Facilitates effective interaction between project participants	Because data is available to project participants in real time, potential issues can be identified and addressed quickly. The potential to reduce project disputes with the CDMS is significant because of the real time availability of project data.
8	Has an acceptable cost profile	A user of the CDMS requires minimal infrastructure - an inexpensive Palm Pilot™ PDA, a PC/laptop (to run the conduit that synchronises the PDA with the database) and a connection to the Internet. Users pay a monthly fee based on the number of checkers. The CDMS has been designed as a one for many application. This reduces the cost for all participants because all receive enhancements rather than tailoring to individual needs. This ensures that the use of the CDMS becomes known across the industry facilitating its acceptance, compared to tailoring the application for individuals, which apart from being prohibitively expensive, negates the move toward an industry standard approach to quality assurance.

Project : Merryville T-Intersection

Contractor : Huon Management
ITP : 1-04 1011 E'works

ITP Worklot Summary

Worklot	Worklot Status	Page No.
North-1011	Closed	9
South-1011	Closed	10

Worklot : North-1011

Verification Point	Criteria	Checked By	Date	Follow Up Action
A.Check clearances obtained	Evidence of services clearances being obtained sighted	Pat OHagan	2005-07-01 13:00:35	
B.Work Method Statement(s)	Work Method Statement available	Pat OHagan	2005-07-04 10:17:22	
C.Confirm setting out	Existing ground levels as per design	Pat OHagan	2005-07-01 13:00:39	
D.Notification of Clearing Operations	Superintendents release of Hold Point 2.1	Pat OHagan	2005-07-26 16:01:15	Fixed 2005-07-26 16:01:11
E.Notification of Earthwork Operations - Survey	Superintendents release of Hold Point 2.2	Pat OHagan	2005-07-26 16:01:23	Fixed 2005-07-26 16:01:20
F.Top Soil and Spoil Areas - Approval of sites	Superintendents release of Hold Points 2.3 and 2.4	Pat OHagan	2005-07-26 16:01:26	
G.Commencement of filling	Superintendents release of Hold Point 2.5	Pat OHagan	2005-07-20 16:23:39	
H.Check levels	Superintendent's Release of Hold Point 2.6 For unpaved areas level + or - 10 mm for highway verges otherwise + or - 50 mm	Pat OHagan	2005-07-26 16:01:41	

Verification Point Field Notes

Verification Point	Note
D.Notification of Clearing Operations	Waiting for Chris Turner to release hold point
E.Notification of Earthwork Operations - Survey	Waiting for Chris Turner to release hold point
F.Top Soil and Spoil Areas - Approval of sites	Waiting for Chris Turner to release hold point
G.Commencement of filling	Fill not required used dgs20 to replace unsuitable
H.Check levels	Waiting for Chris Turner to release hold point

Figure 3 - A sample of a PDF report generated by the CDMS for Huon Management, an early adopter.

8 THE CDMS AND ALIGNMENT WITH A QUALITY SYSTEM

The key element of an effective quality system is a working 'Plan, Do, Check, and Act', or PDCA, cycle. It is the ongoing application of this cycle that leads to continuous improvement in processes and outcomes for business and their customers.

Central to customer confidence, as well as business confidence, is an active non-conformance program where actions (non-conformances) are identified, analysed, and addressed.

Yet, based on the authors' observations the vast majority of quality systems in the industry do not have an effective PDCA cycle, primarily because non-conformances are not being raised at the workface. The statement could be made that, without an effective PDCA cycle, an organisation does not have a true quality system.

Project : Merryville T-Intersection

Followup Actions

No.	Raised	Fixed	Type	Category	Action	Note
1	2005-06-29 08:43:03		Not Defined	Not Defined		Raised page 6
2	2005-07-01 12:57:46	2005-07-26 15:58:57	Other	Other	Consider Improvement Client to be notified - done.	Raised page 8
3	2005-07-04 10:20:10	2005-07-26 15:57:31	Not Defined	Not Defined	Consider Improvement Client to be notified - done. Client approval to action required - given.	Raised page 7
4	2005-07-07 08:32:55	2005-07-26 16:01:11	Other	Not Defined	Consider Improvement Client to be notified - done. Client approval to action required - given.	Raised page 9
5	2005-07-26 16:01:18	2005-07-26 16:01:20	Not Defined	Not Defined	Consider Improvement	Raised page 9
6	2005-07-26 16:17:13		Not Defined	Not Defined		Raised page 15
7	2005-07-27 14:25:39	2005-07-27 14:27:16	Not Defined	Not Defined	Consider Improvement	Raised page 12

Figure 4 –Sample of a CDMS Follow-up Action register

For the first time, the CDMS makes it easy for the checkers to raise, manage and close non-conformances. No separate recording or advising of the issues, no administrative effort – just tick the 'Actions' box, jot a few notes if necessary, and that is it. Closure of the Action is also simple. Once the problem is rectified the Action is closed and the verification point can be ticked as OK.

The CDMS collates this information for a project, in the from of an 'Actions register' (as well as linking Actions raised and closed against specific verification points on ITP reports – refer Figure 4). The Actions provide rich data for analysis to improve processes and practices. Businesses will improve their processes and systems, and customers will see an effective PDCA cycle in action leading to that all important increased level of confidence in the supplier.

Evidence from our initial users of the CDMS is that checkers are raising and addressing 'Actions' as part of their normal work cycle.

9 DEVELOPMENT OF THE CDMS

ABE Services Pty Ltd, the developer of the CDMS, comprises:

- Two engineering professionals with nearly 60 years combined experience in the building and construction industry and some 25 years direct experience in implementing, and consulting on, quality assurance systems, and
- Two IT professionals with some 40 years combined experience in IT development.

This blend of skills has enabled ABE Services to develop an effective solution to quality assurance that fits well with existing quality practices within the industry, and is cost effective in terms of IT infrastructure and technologies.

The CDMS has been developed thanks, in part, to a Knowledge Fund grant from the ACT Government.

A small group of local ACT businesses has assist ABE Services develop the service through their willingness to trial the product. Their subsequent joining with the service has demonstrated their belief in the system.

In September 2005, one of these businesses, NJ Constructions Pty Ltd, received a Highly Commended certificate in the ACT Engineering Excellence Awards run by the Canberra Division of Engineers Australia. The CDMS was a significant part of their submission.

Figure 5 – The manager of Urban Contractors, another early adopter

Decisively, the potential of the CDMS has been recognised by the MBA of the ACT. The marketing of the CDMS is being undertaken in association with the MBA.

10 FUTURE DIRECTIONS

As the CDMS is further developed it is becoming apparent that the CDMS can accomplish much more than just confirm that quality assurance requirements have been met.

Thanks to the ability to time and date stamp all actions the potential exists to link ITPs to relevant project milestones. Linking ITPs to milestones will enable a project manager to monitor actual project progress against the project schedule. By doing so quality assurance requirements will be linked directly to project progress thus putting quality assurance into the main stream of project delivery.

As part of the milestone enhancement a traffic light report will be included, enabling more focussed management of a project through the monitoring of critical aspects of the project.

11 CONCLUSION

The CDMS has been developed to solve a problem within the construction industry – how to deliver effective quality assurance mechanisms to all levels in the industry, and improve the overall performance/productivity of the industry.

The evidence emanating from the initial users of the CMDS is that the checkers are more methodical with quality assurance activities, and many of the checkers are starting to raise and close actions (or non-conformances).

The CDMS, as stated at the start of this paper, provides the vehicle to change the way the building and construction industry views quality assurance – from an administrative hindrance, to an aid to good building and construction practice.

END OF PAPER

MEETING CLIENT NEEDS

Refereed Paper

CLIENT RISK FACTORS LEADING TO COST OVER-RUN IN HIGHWAY PROJECTS

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ABSTRACT

Project cost over-runs create a significant financial risk to both owners and contractors. For the project sponsoring organization, accurate cost estimates are critical to the initial decision-to-build process for the construction of capital projects. However, in spite of the risks involved, the history of the construction industry is full of projects that have been completed with significant cost overruns. Determining the existence and influence of cost overrun risk factors in construction projects can ultimately lead to better control on project cost estimates and assist in identifying possible solutions for avoiding future estimate overruns. This paper describes aspects of the research project that studied client risk factors relating to cost growth in highway construction projects. The research analysed historical data from 238 design-bid-build highway projects, each costing more than A$1m, within Queensland, Australia during the period 1995 to 2003. The paper details 37 low level cost overrun factors that have been identified as causing project cost overrun in highway projects. The paper also details the use of the Nominal Group Technique (NGT) that the research utilised to distil down these low level factors into 10, importance ranked, project risk factor groupings.

Keywords: **client, estimating, government, highways, risk, nominal group technique**.

1.0 INTRODUCTION

Acurate estimates are critical to the initial decision-to-build process for the construction of capital projects. These are usually based on a number of factors such as the complexity of the project, the speed of its construction, the location of the project and its degree of unfamiliarity.

The decision-to-build point in a projects development is seen as the international standard for measuring the inaccuracies involved (National Audit Office/Department of Transport, 1992; World Bank, 1994; Nijkamp and Ubbels, 1999), with accuracy being defined as the difference between the initial project estimate at the decision-to-build stage and the real, accounted project cost determined at the time of project completion.

Expressed as a percentage of estimated cost, this is often termed cost-escalation, cost overrun or cost growth, and occurs as a result of many factors, some of which are related to each other, but all are associated with some form of risk. The analysis of these is a necessary step for the improvement of any given estimating system and can be used to diagnose trouble spots and to pinpoint areas where greater improvement can be obtained

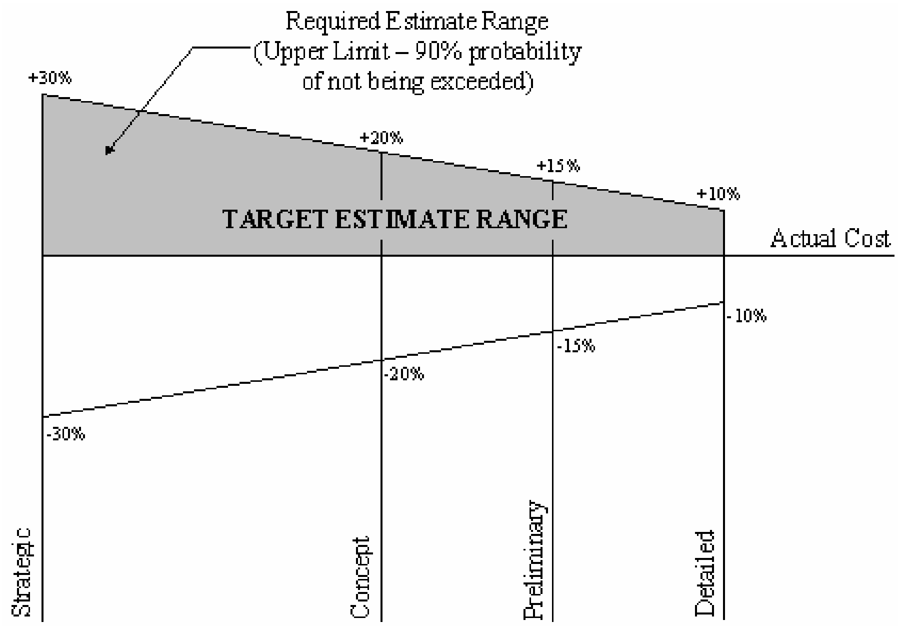
2.0 PROJECT ESTIMATES

It is the goal of the client to estimate as accurately as possible the actual final cost of a project so as not to require funds to be diverted from other projects to cover additional project costs overrun. In the area of highway construction, accurate programming of projects is vitally important to highway organizations as their construction program outlines how highway funds are to be spent over time and any deviation from the stated program often brings a quick response from the public, the press, and politicians. When this occurs, the highway organization loses creditability and time is often taken defending deviation from the published program. On the other hand, if a highway organization can produce realistic program estimates that it is able to abide by, then the image of the agency is enhanced.

For the project sponsoring organization, accurate cost estimates are vital for business decisions on strategies for asset development, potential project screening, and resource commitments for existing and proposed project developments. For a capital project, a cost estimate is prepared to enable the client to make reliable decisions regarding its economic feasibility and its justification. When early project estimates are prepared, they are often based on limited scope definition and little information regarding the specific parameters that will be needed in the completed facility. Pakkala (2002) explains that, while cost estimates become more accurate over time, it is the cost estimate at the time of making the decision-to-build the project that is of primary importance.

Clients’ estimating policies usually focus on the preparation of "unlikely to be exceeded but not excessively conservative" estimates. In the case of highway client organisations, this usually means that the estimate prepared at any stage of a project has a 90% confidence factor of the project budget not being exceeded at the cost at completion. Figure 1 below shows the various % contingency that is normally included in the various stages of project estimates.

Figure 1: Stages and Targets of Project Estimates



Transportation projects have historically experienced significant construction cost overrun from the time the decision-to-build has been taken by the client. A study of 258 infrastructure projects spanning a time period of more than 70 years has found that project costs were underestimated in approximately 90% of the projects, and the actual costs averaged 28% higher than estimated (Flyvbjerg et al., 2002). Highway projects in their research displayed an increase in project costs of more than 20%. From this, it can be argued that construction cost estimating for infrastructure projects, like highways, has not increased in accuracy over the past 70 years.

As well, cost overrun of highway projects in Queensland, Australia, has also been significant over a period of time. The Queensland Government's Roads Implementation Program 2004-05 (Queensland Department of Main Roads, 2005) has reported on the proportion of highway projects costing more than $1m that have exceeded their programmed estimate by more than 10%. As can be seen from Table 1 below, an average of around one in ten projects have incurred significant cost overrun in their budget at project completion, even after the inclusion of substantial provisions for project contingencies.

Table 1: Highway Projects Over $1m Exceeding Budget Estimate by >10%

Year completed	Percentage of highway projects over $1m exceeding cost estimate by >10%
1994	12.3%
1995	7.7%
1996	10.7%
1997	11.4%
1998	12.8%
1999	12.6%
2000	10.4%
2001	6.4%
2002	8.14%
2003	7.82%

Source: QDMR (2005)

3.0 RESEARCH PROJECT

Risks in highway construction projects are characterized by their linear complexity, with their greatest risk lying below ground level due to the relatively larger footprint of highway projects, as compared with, say, building structures.

Studies from around the world have highlighted the recurring frequency of construction risks, such as unforeseen ground conditions. In the USA, studies by (Halligan et al., 1987) on Federal Highway Administration funded state highway construction projects indicated that, whereas claims for ground conditions accounted for only 20% of all claims when categorized by root cause, they were responsible for approximately 35% of the total dollar amount paid to contractors for claims. A study in Hong Kong by (Kumaraswamy, 1997, Pakkala, 2002) that aimed at identifying root causes of claims for extension of time and extra contract payments on construction projects, found that unforeseen ground conditions were ranked fourth in the “top ten” common categories of construction claims.

However, there appears to be limited research within the highway construction industry that identifies risk factors in specific highway project types. The identification of highway project construction risk factors can ultimately provide the client with a better guarantee that the final cost of a delivered project will not exceed the risk adjusted project budget estimate. An understanding of the reasons for such consistent cost overruns should allow clients to focus on problem areas and implement systems into program budgeting procedures which may lead to more realistic project cost estimates.

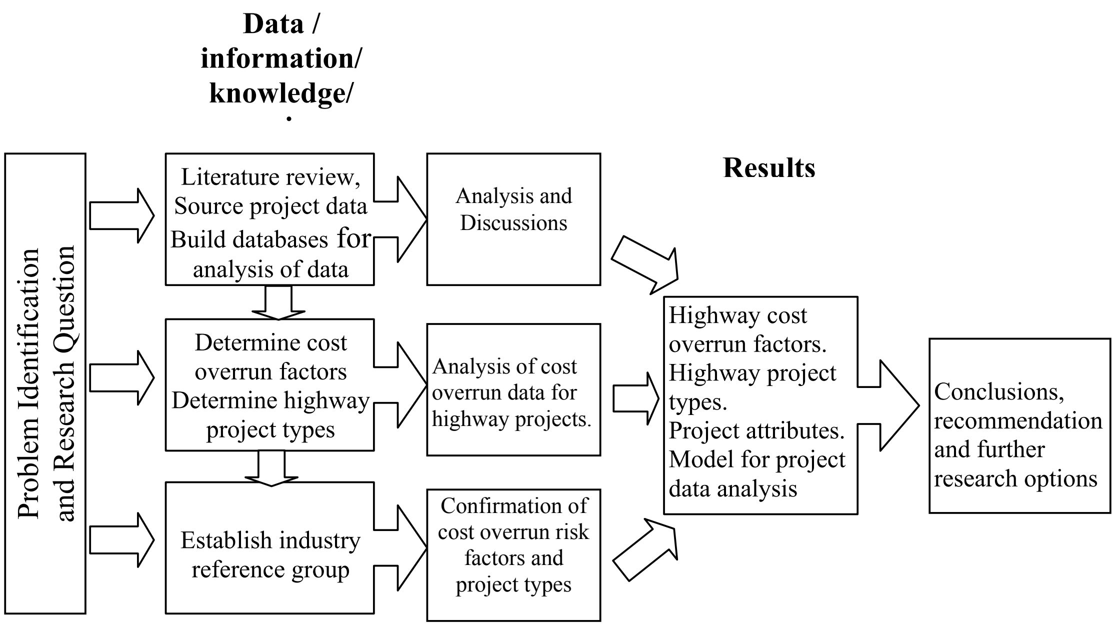
The research project has been undertaken to study the risk factors relating to cost growth in highway construction projects by evaluating the results of historical case study data from completed design-bid-build projects in Queensland. The research question is:

> *What correlations exists between the attributes of particular types of highway construction projects, project risk factors and budget cost overruns that can be utilised for improving client project estimating procedures?*

The purpose of this study is three fold: Firstly, the study is to identify historic project risk factors that cause cost overruns in highway construction projects. Secondly, the project aims to study the types of highway projects that cause degrees of project overrun. Thirdly, a statistical analysis using multiple regression to determine correlations between highway project attributes and cost overrun for various types of highway projects. This paper focuses on the first element of the research.

The main activities of the research are presented in Figure 2 below.

Figure 2: Research Main Activities



This research adopts both the case study and historical research methodologies. These methodologies were chosen because:

- The cases study is considered an important approach for presenting information, describing the issue at hand and prescribing solutions or treatments (Kirszner and Mandell, 1992). As well, it allows the utilisation of historical data to assist in providing an insight into current problems relating to cost overruns in highway project estimates by examining what has happened in the past.
- The case study's unique strength is its ability to deal with a full variety of evidence like documents, interviews and observations (Yin, 2003).
- Historical research is concerned with historical problem, or it may be a historical approach to a contemporary problem. A key difficulty with historical research is separating out fact from opinion or myth. Bennett, (1991) points out that when the problem under investigation is of more recent historical origin, then data and facts may be available but not collected in an ideal form that is required to describe and understand the problem.

The research case study focuses on the highway and bridge network within one particular state of Australia, namely the state of Queensland. This state has been chosen as a representative case study because of its unique features. The state is expected to experience a 50% population increase over the next 25 years, making it the fastest growing state in Australia, and possibly the most populous state in 30 years. Road freight demand is expected to double over the next 20 years. This growth will continue to place increasing pressure on Queensland's highway network to handle significant increases in travel. As well, there is no other highway network in Australia that has a combination of unique and diverse geographic and functional constraints or limitations that must be managed by the one highway organisation.

The Department of Main Roads is the agency responsible for 34,000 kilometres of Queensland's highway network, representing 20 per cent of the state's total road network of 174,000 kilometres. It has 2,740 bridges and 20,000 major culverts. This highway network represents the state's largest single physical asset, with a replacement value of A$26.6 billion (2003).

4.0 PROJECT DATA

Historical highway project construction data was collected from the published Roads Implementation Program documents of the Queensland Department of Main Roads (QDMR) over the period from 1995 to 2003 and were available as a number of related public documents. The construction project data obtained covered 78 different Local Authority geographic areas of the State of Queensland out of a total of 125 and so represents state highway works in 65% of the administrative regions of the state of Queensland.

The client data was extracted from publications of the Queensland Department of Main Roads for the years 1995 to 2003 in the format shown in Table 2 below. The table shows two samples of highway construction projects that were completed in the 2002-2003 financial year.

Table 2: Sample Data of Highway Construction Projects

Project Number.	**Location**	**Description of works**	**Method of delivery**	**Programmed cost $m**	**Actual cost $m**	**%**
13/25A/48	Mount Lindsay Highway (Brisbane – Beaudesert Road)	Construct Interchange	Open Tender	8.649	9.835	13.71
	Reason: Increase due to contract cost higher than originally estimated and change of project scope to include raised central median					
99/332/10	Pitsworth - Felton Road	Realign two lanes	Sole invitee- Local Government	1.000	1.246	24.60
	Reason: Increase due to removal and replacement of unsuitable subgrade material, lighting and service relocations and additional drainage.					

. The project data that was available from this source included the following:

1. Project identification number.
2. Local Authority in which the project was delivered.
3. The highway name on which the project was built.
4. The project location within the particular highway.

5. Description of the project type that was constructed.
6. Method of project delivery (open tender contract, negotiated contract).
7. The programmed project budget estimate.
8. Actual final project cost.
9. Percentage cost overrun.
10. Reason(s) for project cost overrun

The actual final project cost shown in No. 8 above includes the cost of all component activities, from the project design to project construction finalisation. It included the cost of:

- conducting investigations and developing the design,
- detailing the design,
- acquiring land,
- altering public utility plant,
- construction,
- project administration, and handover

The 238 projects analysed in the research were highway construction projects whose initial estimated project cost was more than A$1.0m and whose final cost exceeded the original estimate by greater than 10%. The total combined project value of these projects was A$1.015b.

The project delivery process of all of construction projects was carried out using the "traditional" design-bid-build method. This method consists of the design/engineering services being procured first, and then another procurement contract was tendered for the actual construction of physical works, based upon the design/engineering portion of the project. There appears to be considerable support worldwide for the delivery of infrastructure projects, such as highways, using the traditional method. Pakkala (2002) found that, in a global perspective, delivery of infrastructure services and products for capital investment projects varied in practice from country to country. However, in evaluating highway infrastructure project delivery in Australia, Canada, England, New Zealand, Sweden and the USA, he reported that all used a common practice for the main delivery model, known as the traditional model, or design-bid-build.

5.0 PROJECT DATA ANALYSIS

A systematic analysis of the data for each of the 238 highway projects was undertaken by the author. The reasons for cost overruns were documented for each project and a final list of 37 cost overrun variables was determined. Table 3 below shows these cost overrun variables, as well as the number of occurrences each had across the projects reviewed.

Table 3: Cost Overrun Project Variables and Occurrences.

Cost overrun variable	Reason code	Occurrence
Design/project scope change	D	95
Contract tender price higher than original estimate	TH	35
Design scope change - Drainage	DD	33
Quantity increased measure	Q	31
Design Scope Change - pavement materials/depth	DM	23
Latent Condition - Remove and replace unsuitable material	LUS	21
Design Scope change - Environmental issues	DE	19
Constructability - under traffic	CT	17
Services relocation costs	S	12
Material cost increase – Pavement Materials	MP	11
Constructability difficulty costs	C	10
Resumption/accommodation works	R	10
Project Administration Cost Increase	P	8
Wet Weather Effects/Rework	WW	8
Latent Condition - Rock encountered	LR	7
Remote location costs	O	7
Specification Change	SC	7
Extras Unspecified *	EU*	6*
Project acceleration requirement	A	5
Design Scope Change - Safety Audit Requirement	DSA	4
Cultural heritage issues	H	4
Latent Condition - requires design change	LD	4
Material cost increase - Principal supplied components or materials	MPS	4
Government Initiative – Contribution by Developer	GCD	3
Latent Condition - Additional Stabilising	LSG	3
Material cost increase - Earthworks	ME	3
Design Scope change - Design error	DF	2
Material/Process Quality Issue	MQ	2
Design Preload Requirement	DPL	1
Design Change to Subgrade	DSG	1
Government Initiative - Employment continuity	G	1
Government Initiative - Contribution by Local Government	GCLG	1
Government Initiative - Contribution by Rail	GCR	1
Material cost increase - Asphalt	MA	1
Material cost increase - Bitumen Price	MB	1
Contract failure-New contract establishment costs	N	1
Contract Tender Price Increase due to inflation	TCI	1

(* For the purpose of the research, the cost overrun variable "Extras Unspecified - EU" occurred across six projects. Review of the individual projects showed that the occurrences were all attributed to one particular type of project, namely the construction of 8 lanes of highway on the various stages of the Pacific Motorway project that links Brisbane to the Gold Coast in the south-east of Queensland. Further investigations identified that it was not possible to obtain any detailed public cost overrun details for those specific projects because of the various deeds of agreement of contract finalization arrangements.)

Table 4 below shows the relative percentage occurrence of the 12 highest cost overrun variables.

Table 4: Percentage Distribution of Top Twelve Variables.

Design/project scope change	D	31%
Contract tender price higher than original estimate	TH	11%
Design scope change - Drainage	DD	10%
Quantity increased measure	Q	10%
Design Scope Change - pavement materials/depth	DM	7%
Latent Condition - Remove and replace unsuitable material	LUS	7%
Design Scope change - Environmental issues	DE	6%
Constructability - under traffic	CT	5%
Services relocation costs	S	4%
Material cost increase – Pavement Materials	MP	3%
Constructability difficulty costs	C	3%
Resumption/accommodation works	R	3%

The next step in the research process was to distill down the high number of cost overrun variables recorded into a smaller number of high level risk groupings.

6.0 ELICITING PRINCIPAL COST OVERRUN GROUPINGS

There are a number of techniques available that provide opportunity to evaluate tacit knowledge based on the experience of individual practitioners. The three expert elicitation techniques considered for this stage of the research project were:

- Focus group
- Delphi
- Nominal group technique

However, in the rapidly paced world of construction management , an expert elicitation method needs to be nimble and efficient because experts in construction management are continually confronted with not having enough time for all the activities required of them (Laufer, 1996). Consequently, the selection of the elicitation technique was determined to a large extent by the time that experts could allocate to this stage of the research project.

The Nominal Group Technique was adopted because of its low impact on the groups' available time. Originally developed as an organizational planning technique by

Delbecq, Van de Ven and Gustafson in 1971, the nominal group technique is a consensus planning tool that helps prioritize issues. The technique presents a more structured approach than the focus group, but still takes advantage of the synergy created by group participants. The nominal group technique involves a process similar to the Delphi method (Dalkey, 1968) with the objective of the technique being the exploration and ranking of ideas from a team of experts (Adler and Ziglio, 1996). As its name suggests, the nominal group technique is only "nominally" a group, since the rankings are provided on an individual basis.

Some of the other advantages that were considered in adopting this process were:

- Voting was anonymous,
- There were opportunities for equal participation of group members and
- Distractions such as communication "noise" that is inherent in other group methods were minimized.

Another advantage was that the technique was able to draw more attention from an expert team to each item and increase the opportunity for each member to ensure that their ideas were part of the group's frame of reference (Delbecq et al., 1986). The technique prevents the domination of discussion by a single person, thus encouraging the more passive group members to participate.

The composition of the expert elicitation team was based on Keeney and von Winterfeldt (1991) research which recommended that a quality expert elicitation process should involve at least three types of participants;

- specialist
- analyst, and
- generalist

Specialists

The identification and selection of the specialists is crucial, since the specialist's judgements can be scrutinised in detail. As well, the specialist has the command of knowledge and flexibility of thought to apply their expertise to the issue at hand and are capable of translating their knowledge into judgements relevant to the problem.

Analysts

The analysts task is seen as assisting the specialists to formulate the issues, to decompose them, to articulate their judgements, to check the consistency of the resulting numbers, and to help document the specialist's reasoning.

Generalists

The generalist is an expert with a broad knowledge about many or all of the issues to be studied as well as knowledge a project issue. Generalists can excel at communicating with the specialists and in translating issues into the specialist's language. Generalists facilitate the essential bridging between various issues.

Group Composition

Clemen and Winkler (1985) suggests that five specialists are usually sufficient to cover most of the expertise and breadth of opinion Depending on the issues at hand and on the number of specialists selected, there may be a need for an additional two or three generalists and two or three analysts

The NGT group for the expert elicitation composed of the following table 5:

Table 5: Nominal Group Elicitation Composition

Nominal Group Member	Number
Analyst	1
Generalist	2
Specialist	4
Researcher	1

The nominal group participants devised ten principal cost overrun groupings and used numerical scores to express their individual opinions on the level of importance of each. They were then able to rank those groupings as shown in Table 6 below in terms of their cost overrun impact to a project. They used a weighting of 1 to 10 for the ten groupings, with 1 representing the most important high level factor that posed the most potential for causing cost overruns in highway projects.

Table 6: Principal Cost Overrun Groupings and Ranking**.**

RANK	**High Level Risk Group**	**Low Level Factors**								
I	Design and Scope Change	D	DD	DE	DM	DSA	Q	SC		
II	Insufficient Investigations and latent conditions	DPL	DSG	LD	LR	LSG	LUS			
III	Deficient Documentation (Spec and Design	DF								
IV	Client Project Management Costs	A	G	GCD	GCLG	GCR	MQ	N	P	TH
V	Services Relocation	S								
VI	Constructability	C	CT							
VII	Price Escalation	MA	MB	ME	MP	MPS	TCI			
VIII	Right of Way Costs	R								
IX	Contractor Risks	O	WW							
X	Environment	H								

The following describes the composition of the final ten groupings in rank I to X.

Rank I: Design and Scope Change:

- Design/project scope change.
- Design scope change resulting from drainage, environmental issues, pavement materials/depth.
- Design Scope Change as a result of carrying out a safety audit on the project.
- Quantity increase.
- Specification Change.

Rank II: Insufficient Project Investigations and Latent Conditions:

- Design preload requirement.
- Design change to subgrade.
- Latent Condition - Requiring design change.
- Latent Condition - Rock encountered.
- Latent Condition - Additional stabilising.
- Latent Condition - Removal and replacement of unsuitable material.

Rank III: Deficient Documentation (Spec and Design):

- Design Scope Change - Design error

Rank IV: Client Project Management Costs:

- Project acceleration requirement.
- Government Initiative - Employment continuity, Contribution by developer, Contribution by Local Government, Contribution by Rail.
- Material/Process Quality Issue.
- Contract failure-New contract establishment costs
- Project administration cost increase
- Contract tender price higher than original estimate

Rank V: Services Relocation.

Rank VI: Constructability:

- Constructability difficulty costs.
- Constructability - under traffic.

Rank VII: Price Escalation:

- Material cost increase – Asphalt, bitumen price, earthworks, pavement materials, Principal supplied components/materials.
- Contract Tender Price Increase due to inflation

Rank VIII: Right of Way Costs:

- Resumption/accommodation works

Rank IX: Contractor Risks:

- Remote location costs
- Wet Weather Effects/Rework

Rank X: Environment:

- Cultural heritage issues

7.0 CONCLUSION

The analysis of cost overrun factors is important for the improvement of any given estimating system and can be used to diagnose trouble spots and to pinpoint areas in estimates where the greatest improvement can be obtained at the lowest expense. Determining the existence and influence of these cost overrun risk factors in highway construction projects may ultimately lead to better control on project costs and assist in identifying possible solutions to avoiding future cost overruns.

This paper has looked at the analysis of cost over-run risk factors that were identified throughout 238 highway construction projects between 1995 and 2003. The project sample represented 65% of the administrative area of the state of Queensland. The highway projects were initially analysed by means of a systematic review of each project and the cost overrun reasons documented for each project.

A list of 37 cost overrun variables was obtained.

Further analysis of the variables was carried out using expert elicitation and the nominal group technique. Ten high level cost overrun groupings were developed and ranked in importance that contribute substantially to project cost overrun.

In the initial data analysis and in the expert elicitation process, *Design/project Scope Change* was ranked first in both instances. Literature research supports this findings in that engineering designs have a high level of influence on project costs (Barrie and Paulson, 1992) and unsatisfactory design performance can lead to cost over-runs (Chang, 2002). Many construction problems are due to design defects and can be traced back to the design process (Bramble and Cipollini, 1998).

The analysis of historic highway construction data has shown that there are consistent budget cost overruns in a significant number of completed projects over time, even with the incorporation of substantial on-cost % contingencies. This would demonstrate that further research is required with a focus on project estimating and project delivery methods that can limit project scope change after the decision-to-build has been made by the client.

The use of the nominal group technique for expert elicitation was found to be very effective. All members noted the effectiveness of the technique, especially in obtaining group agreements with the minimum expense of the experts' precious time. The selection of nominal group membership is seen as being important to the success of this technique and can entail a broad search of participants with emphasis on differences of opinion and a broad range of expertise relevant to the project issues.

All highway data collected and analysed in this research were obtained from a single Government highway source. Therefore, in its present context, the findings should only be applied to highway infrastructure projects in Queensland, Australia. It should also be noted that some of the research project data may be related to economic conditions and contracting climates which may have varied from time to time during the analysis period. In addition, the project data was extracted from public sources. Whilst this has overcome some of the difficulties that some researchers are presented with in trying to obtain realistic historical project data, it has also limited the quality and depth of data mining that was able to be carried out due to limitations in public access to organisations' project archives.

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MEETING CLIENT NEEDS

Case Study

QUALITY SPECIFICATIONS FOR CLIENTS

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ABSTRACT

NATSPEC, publishers of the National Building Specification, aims to contribute to the improvement of the quality of construction in Australia. Clients prefer NATSPEC specifications because they provide assurance of a baseline level of project quality. Whilst drawings and schedules provide details on the form and materials of a project, it is a properly constructed specification that sets the quality requirements.

The number of regulations that change each year continues to increase. Pressures on consultant's fees and the time available for design do not allow individual organizations to monitor all the regulatory changes. NATSPEC provides the economies of scale to track changes and to keep consultants up-to-date. The end result is better documentation that gives clients a more reliable basis for assessing tenders and construction.

This presentation overviews the advantages of a national master specification system and how the NATSPEC system meets client's needs.

Keywords: Design, Documentation, Quality, Specification

1.0 INTRODUCTION

> *Poor documentation is contributing an additional 10-15% or more to project costs in Australia. The annual cost to the Queensland construction budget is a financial loss of $2 billion every year! This equates to a loss Australia wide of at least $12 billion.*[1]

The client's brief is the driving force for innovative responses to building projects. Innovations are design solutions arising out of the brief and may be related, for example, to the site, the budget, aesthetics, re-use of existing structures, or to passive and active systems aimed at energy efficiency.

Clients desire a project that meets or exceeds expectations within the constraints of location, time and cost. The majority of clients do not impose impossible constraints; rather it is often the competitive fee process or failures in communication that lead to substandard documentation. Failures in communication include not having a common language and different interpretations of the documentation.

It is the documentation phase of building procurement that ensures ultimate success or failure to transform the design to reality. Documentation involves the production of drawings, schedules and specifications, which form part of the contract documents of each project. The specification is read in conjunction with the drawings; drawings and schedules provide information on **quantity**, and the specification on **quality**. A succinct and unambiguous specification is a prerequisite for a quality outcome.

2.0 QUALITY

Quality is a subjective matter meaning different things to different people depending on perceived priorities. People's ability and willingness to pay for a particular level of quality is also varied.

2.1 THE BCA

An indication of the level of the quality benchmark set by the Building Code of Australia (BCA) is given in the Australian Building Codes Board (ABCB) objectives, mission statements and goals as follows:

> *The objectives to which the proceedings and operations of the Board are to be directed are to ensure that building requirements are based on minimum, least cost solutions commensurate with regulatory objectives of health, safety and amenity*[2]

The ABCB's mission

> *The ABCB's mission is to provide for efficiency and cost effectiveness in meeting community expectations for health, safety and amenity in the design, construction and use of buildings through the creation of nationally consistent building codes, standards, regulatory building requirements and regulatory systems*.[3]

[1] *Getting it right the first time*, Engineers Australia Queensland, October 2005
[2] Inter-Government Agreement between The Commonwealth of Australia, The States and The Territories to establish The Australian Building Codes Board March 1994, as amended 27 July 2001.
[3] www.abcb.gov.au

The BCA itself also outlines its goals as being '*…to enable the achievement and maintenance of acceptable standards or structural safety (including from fire), health and amenity for the benefit of the community now and in the future. These goals are applied so that the BCA extends no further than is necessary in the public interest, is cost effective, easily understood, and is not needlessly onerous in its application.*'[4]

The BCA alone will not provide for compliance at an acceptable minimum baseline of quality.

2.2 AUSTRALIAN STANDARDS

Another benchmark of quality is the vast library of Australian Standards. These have been summarised by Standards Australia as:

> *'… the tools we use to organise our technical world and the measures we employ to establish norms for management procedures. They underpin consumer expectations that products purchased will be safe, reliable, and fit-for-purpose.'*[5]

3.0 NATSPEC

NATSPEC is a not-for-profit organization that was set up in 1975 to provide assurance of a baseline level of quality by providing a national master specification system to the building industry. The specification is for all building structures with specialist packages for architects, interior designers, landscape architects, structural engineers, service engineers and domestic owner/builders.

A national master specification was desired because it is not economical or efficient for each individual consulting practice to monitor all the changes in regulations, standards and product/technology improvement. Further, there are huge efficiency gains when the national master specification is so commonly used that the expectation of a known level of quality is taken as standard. Further, in Australia, it is appropriate that the system is national because the building industry is national with common materials, construction techniques and procurement strategies.

A quality specification must clearly demonstrate compliance to the BCA and other relevant authorities. NATSPEC identifies these issues and offers guidance to the writer for implementation. The benchmark of quality set by the BCA is built upon by the incorporation of Australian Standards and feedback from industry. A report by the late Bryce Mortlock, the founder of NATSPEC noted:

> *'Nothing could be more necessary, more logical, more timely or more useful in today's building industry or more responsive to the call for quality control than a specification system tied to relevant Australian Standards.'* [6]

NATSPEC remains true to these sentiments. A large number of Standards in addition to those referred to in the BCA are cited and where appropriate, some worksections are predicated on a Standard e.g. *Brick and block construction* is built around AS 3700.

NATSPEC responds to industry directly by a review process of new material utilising experts drawn from designers, manufacturers and industry bodies. The response from these outside reviews is incorporated and ensures continuing relevance. This review process takes advances in material development, construction efficiency and ability, and cost into account.

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[4] BCA 2005, Vol. 1, p.7.
[5] *Standards and Standardization,* Standards Australia.
[6] RAIA Practice division report, *NATSPEC*, August 1989.

4.0 CONSEQUENCES OF POOR QUALITY IN DOCUMENTATION

There is growing concern on the issue of quality building within the industry in Australia as highlighted by a number of recent articles commenting on the link between poor documentation and the consequent effects on projects.

4.1 THE PROBLEM

CSIRO noted:

> *From a contractors' perspective, the deficiencies occurring in design and documentation being provided by consultants, have been steadily increasing over the past 12-15 years and are causing corresponding increases in the extent of inefficiency within the construction process. As a consequence, decreases in project quality and increases in overall project costs result. Of major concern are the additional costs – which to a large degree end up being absorbed by contractors – caused by the delays and disruption in trying to clarify inadequate, impractical, conflicting or ambiguous design and specification documentation.*[7]

More recently, at the *Construction Forum on the declining standard of project documentation*, held in May 2004, the President of Engineers Australia Queensland Division, Peter Jorss said:

> *'The impact of inadequate documentation at the planning and implementation stages actually leads to increased construction costs, and unfair economic and time pressures on participants delivering services for the projects.'* [8]

An ACIF (Australian Construction Industry Forum) media release following the forum notes:

> *Extensive case study research presented at the Construction Forum highlighted that poor design and documentation leads to: major cost over-runs; re-work and extensions of time; high stress levels; loss of morale, and reduced output; adversarial and unethical behaviour; and declining safety standards.*[8]

4.2 TOWARDS A SOLUTION

The CSIRO noted in their 2000 survey report that improvement in construction efficiency would result from creating awareness of the benefits of quality design and documentation.

> *Improvements in construction process efficiency will result from creating an awareness of the value of quality design and documentation…The benefits would be more projects being completed on time, within budget and with a reduced likelihood of legal action due to contractual disputes. Also, with less RFIs, variations and rework, contractors would be able to minimise the management time and cost spent on non-value adding activities. These benefits would be reflected in reduced project and contractual risk, and a higher level of profitability for both clients and contractors.*[7]

[7] *A Survey investigating changes in Design and Documentation Quality within the Australian Construction Industry and its effect on Construction Process Efficiency,* CSIRO, 2000.
[8] ACIF media release, 11 May 2004.

As part of recommended solutions Engineers Australia suggests the promotion of:

> *'…the development and use of purpose-built contract technical specifications under which the project designer/specifier assembles a technical specification specific to his/her project…'* [9]

It notes NATSPEC as one of such systems currently in use in Australia.

> *'…The NATSPEC system which provides a comprehensive national specification system endorsed by 20 major State and Federal government and professional bodies including Standards Australia.'* [9]

4.3 TIME AND FEES

In order to begin addressing the problem, it is of interest to note that the CSIRO Survey report relates the cause of the problem of decrease in design and documentation qualities to pressure on time and fees:

> *'It is the belief of the authors based on the responses of the surveys that the reduction in the level of design fees together with a reduction in the time made available to carry out the work, has caused a decline in the quality of design and documentation.'* [10]

It would seem that improvements to design and documentation, and therefore construction quality, could be addressed by a number of means. One is by educating those involved in the building process (ie. clients, developers, designers and builders) on the benefits, time required and costs to provide good documentation.

Another would be in improving on the efficiency with which documentation is produced.

5.0 SPECIFICATION METHODS

There are a range of sources that can be used to produce new specifications. Each has its merits and problems. Although there are many approaches, perhaps as many as there are projects and specification writers, most can be reduced to a combination of the following:

Use raw data: That is, write it from scratch using a manufacturer's or similar data. There will always be situations where new methods, materials or situations make the creation of new material from raw data necessary. To produce a specification in this way requires careful research and is time consuming. It is not a preferred method or even desirable for whole specifications because of the risk that many important issues will be overlooked.

Adapt a previous project specification: This method reduces the time required and offers the opportunity to fix errors (if they are remembered or even known) in the previous document. It is a very risky approach because parts of the new specification can be guaranteed to be out of date (for instance not matching current BCA requirements) and material intentionally omitted from the original specification may be critical to the new. This is a quick fix method that often results in inconsistencies with the drawings.

Use a proprietary specification: This involves the use of specification material provided by a supplier or manufacturer. It has the advantage that the specification should match the

[9] *Getting it right the first time*, Engineers Australia, June 2005.
[10] *A Survey investigating changes in Design and Documentation Quality within the Australian Construction Industry and its effect on Construction Process Efficiency,* CSIRO, 2000.

supplier's material. Apart from the obvious negative of giving one supplier a monopoly, such specifications may not provide protection for the clients interests, may be poorly written contractually and, because they are often not regularly updated, may not reflect current regulatory requirements or industry practice.

Use an office master specification: This offers the potential to create specifications that suit an office's policies and expectations of their clients. It can also provide a means for covering types of work that the office specializes in that is not available from other sources. The intellectual property contained in such specifications, if well done, may represent a significant investment and maintaining a quality office master represents a significant financial and management commitment. In practice the quality of the result can vary considerably over time and with management and technical commitment. Even if initially well written, regularly reviewed and revised, such specifications represent the opinion of only one group and are unlikely to incorporate the input of significant stakeholders.

More importantly, they are at best a specification, not a specification system. That is, even if such a master is an excellent architectural or engineering specification and well coordinated internally, it will not be coordinated with other disciplines outside the office. To address this requires detailed review of all input documents on a project-by-project basis. If such a detailed review is either absent or superficial, the result can be undesirable duplication of material or omissions, both sources of contract variations.

Use a national master specification system: The International Construction Information Society (ICIS) is an association of organizations that provide national master specification systems. Countries represented include Australia, Belgium, Canada, Czech Republic, Finland, Germany, Japan, Netherlands, New Zealand, Norway, South Africa, Switzerland, UK and USA. It exists because it is internationally recognized that national master specifications add value to their nations as a whole and that in the long-term there is value in moving towards international harmonization. Such a national master specification system offers the potential to address shortcomings in the previous four methods without introducing undesirable new ones. A 'perfect' Australian specification system should address the following:

- It should be easy and efficient to use.
- It should be cost effective.
- It should be frequently, if not constantly, updated to reflect changes in standards and regulations.
- It should reflect current practice in the industry in Australia.
- It should be consistent and part of a coordinated specification system that covers the whole of the project, not just part of it.
- It should respond to the comments of all stakeholders in the industry.
- It should be aimed at producing a quality built result at a competitive price.
- It should reduce uncertainty by providing a predictable structure with consistent content.

6.0 A QUALITY SPECIFICATION

According to the CSIRO survey report, pressure on consultant's fees and programmed production time appear to be key components to the decline in documentation quality. By using a regularly maintained master specification template, time is saved in the production process and customised project specifications are always up-to-date with current BCA and standards.

NATSPEC has always provided the national specification system, with the aim of providing economies of scale for its shareholders and of improving the quality of construction in Australia through its provision of information, tools, products and services. The regular development and updating of the specification system in response to user and industry feedback is a part of the process of providing NATSPEC products to its subscribers with the aim of making it easier and more efficient to document quality buildings.

The advantage of using NATSPEC is that builders and contractors generally can see more certainty and predictability in specifications because the standard is consistent across projects with a reduced likelihood of idiosyncrasies of individual specification writers.

Recent developments in NATSPEC include the introduction of the new classification system in 2005 providing an industry structure for information with the flexibility to include new worksections into the overall classification in the future. The classification system also permits users to incorporate office-edited worksections and provides the framework for the SPECbuilder Pro specification compilation software that improves the efficiency of the specification production process.

7.0 NATSPEC CLASSIFICATION SYSTEM

> *'The grouping of this material into logical subdivisions is the obvious starting point in the preparation of a specification… We also must recognize the best of local contracting and construction techniques and attempt to anticipate the future.'* [11]

All specifications have a structure. A classification system provides a consistent structure that means it is easier to find both existing material and a place for new. Other benefits of a classification system are:

- Readers know where to find things. Writers know where to find existing things and where to put new.
- Builders can confidently break up specifications, including all relevant parts in a work package, because the classification system means that things are consistently located.
- Head and sub-consultants know where things are and so don't leave them out or duplicate them e.g. because the hydraulic consultants know that the *Service trenching* worksection is in Group 1 they will not duplicate it in their hydraulics specification.
- Potentially contractors should be able to reduce margins because the predictability of the classification system makes for less uncertainty.
- Finally the structure that exists in the Group and worksection numbering extends to the internal structure of the worksection. All worksections have the same basic structure so a reader or writer always looks for the same thing in the same place. Samples and definitions, for example, are always in the same place, not scattered through the worksection.

There are several classification systems in use internationally such as CAWS (UK) and MasterFormat (USA). NATSPEC gave considerable thought to adopting one of these widely used systems in preference to creating its own. The problem with another country's

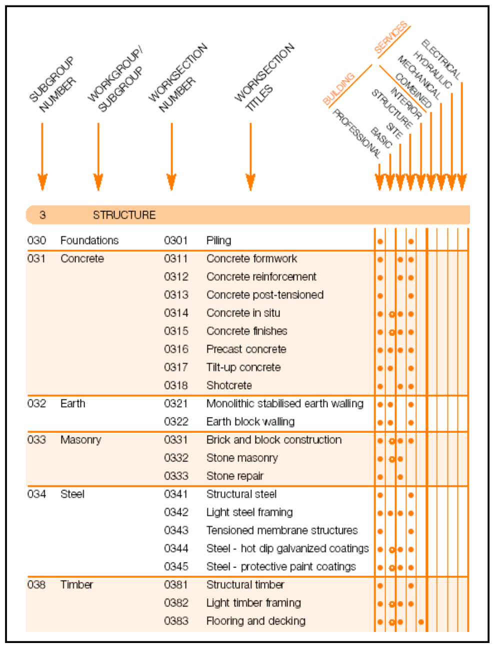
[11] RAIA Practice division report, *NATSPEC*, August 1989.

approach is that it reflects the building industry in that country and not Australia's. For example, in the United States, mechanical and hydraulic services are handled by the same contractors and therefore are included in the same Division in their classification system. For NATSPEC to have adopted the US system would have involved compromises and adaptations that would have made the result neither a US nor Australian classification system, destroying the hoped-for benefit of an international system.

NATSPEC chose to develop a classification system that reflects the Australian construction sequence and industry. While not broken up into traditional trades, it is designed to facilitate packaged contracting by allowing several individual worksections to be incorporated into a trade package. Its modular nature also permits material that might be common to several trade packages (for example *Service trenching*) to be easily duplicated in the packages ensuring a consistent quality.

NATSPEC's classification system is based on nine work groups housing sub-groups and worksections.[12]

Workgroup	Worksections
1. GENERAL	0100 to 0199
2. SITE	0200 to 0299
3. STRUCTURE	0300 to 0399
4. ENCLOSURE	0400 to 0499
5. INTERIOR	0500 to 0599
6. FINISH	0600 to 0699
7. MECHANICAL	0700 to 0799
8. HYDRAULIC	0800 to 0899
9. ELECTRICAL	0900 to 0999



Above: The 9 workgroups
Right: Example of the organisation of sub-groups and worksections within workgroup 3: Structures

8.0 MAINTENANCE

> *'The ongoing updating of NATSPEC material keeps pace with the changes to legislation, the BCA and Australian Standards and this gives NATSPEC subscribers the confidence to know that their project specifications will comply with the very latest requirements'.*[13]

One of the principal advantages of a national specification system like NATSPEC's is that it draws on a wide range of people and organizations. Internally NATSPEC uses an interdisciplinary team of editors with specialist expertise in the range of disciplines normally

[12] Refer Appendix A for the NATSPEC classification system.
[13] Peter Radtke, The Northern Territory Department of Planning, 2005.

present in a building design team. When less common areas are to be approached (like specifying trees) NATSPEC engages outside specialists to draft material. Having drafted a new or significantly revised worksection NATSPEC submits it to relevant stakeholders across Australia including specifiers, suppliers, contractors and client organizations.

Keeping NATSPEC current, and therefore relevant to subscribers and industry is an involved process. The evolution of NATSPEC material relies on many sources including:

- Amendments to the BCA and over 1000 cited Standards
- Subscriber/user feedback
- Shareholder feedback[14]
- Collaboration with global master specification providers
- Editorial team experience, knowledge and input.

By these means NATSPEC accumulates and maintains quality information. The result is quality practice within realistic cost constraints.

NATSPEC provides and maintains the following material to its subscribers:

1. The NATSPEC Classification System revised annually to include new worksections and to reflect revisions based on industry information and advancements.

2. Specification packages, issued via CD-Rom, with regular updates. SPECBuilder Pro, which is a specification compilation software program is also provided as part of the package. Current packages are:

- *BUILDING Professional*
- *BUILDING Basic*
- *BUILDING Site*
- *BUILDING Structure*
- *BUILDING Interior*
- *SERVICES Combined*
- *SERVICES Mechanical*
- *SERVICES Hydraulic*
- *SERVICES Electrical*
- *DOMESTIC*

3. *NATSource* is a listing of all sources of citations in the worksections. This is updated and issued with the major annual package updates.

4. *Standards revising NATSPEC* is a cumulative listing of all new and revised standards over the year which relate to NATSPEC worksections. It is updated on a monthly basis and made available to subscribers on the NATSPEC website.

5. *SPECnotes* is the NATSPEC newsletter. It is mailed to subscribers on a quarterly basis, and incorporates listings of new and revised standards over that period that relate to NATSPEC worksections. It is also made available on the web.

6. *TECHnotes* are 1-page summaries of issues relating to more than one worksection. They are posted to the NATSPEC website monthly and one is included with SPECnotes quarterly. They are also used by the NSW RAIA for their Continuing Education program and, when appropriate, will be used by organizations including, Engineers Australia, Australian Institute

[14] Refer Appendix B for a list of NATSPEC shareholders.

of Quantity Surveyors, Australian Institute of Building and the Building Designers Association of Victoria.

9.0 CONCLUSION

A well maintained purpose-built technical specification system is key to producing quality documentation. The benefits of quality documentation include reduced project clarifications, variations, re-work and a reduced likelihood of legal action due to contractual disputes. It is only through quality documentation that clients can be assured of a quality result.

Again, in the words of Bryce Mortlock:

> *'Unfortunately the level of quality that can be policed in the construction stage cannot be higher than that which is spelt out in the contract. If the building contract documents permit a sow's ear then all the quality control in the world cannot demand a silk purse.'*[15]

Quality is reliant on good documentation and good documentation is incomplete without a good specification.

[15] RAIA Practice division report, *NATSPEC*,1989.

APPENDIX A: THE NATSPEC CLASSIFICATION SYSTEM

NATSPEC WORKSECTION CLASSIFICATION LIST - 2006

1 GENERAL

0121 Tendering
0122 Tendering (Interior and alterations)
0123 Package contracting - scopes
0131 Preliminaries (Generic)
0133 Preliminaries (Generic interior and alterations)
0141 Preliminaries - ABIC MW-1
0142 Preliminaries - ABIC SW-1
0143 Preliminaries - AS 2124
0144 Preliminaries - AS 4000
0145 Preliminaries - AS 4905
0146 Preliminaries - AS 4902
0161 Quality
0171 General requirements
0172 General requirements (Interior and alterations)
0173 General requirements (Mechanical)
0174 General requirements (Hydraulic)
0175 General requirements (Electrical)
0176 Environmental management
0181 Adhesives, sealants and fasteners
0182 Fire-stopping
0183 Metals and prefinishes
0184 Termite management
0185 Timber finishes and treatment
0186 Building IT components

2 SITE

0201 Demolition
0221 Site preparation
0222 Earthwork
0223 Service trenching
0224 Stormwater - site
0241 Landscape - walling
0242 Landscape - fences and barriers
0251 Landscape - soils
0252 Landscape - soft surfaces
0253 Landscape - plants
0254 Irrigation
0255 Trees supply
0261 Landscape - furniture and fixtures
0271 Pavement base and subbase
0272 Asphaltic concrete
0273 Sprayed bituminous surfacing
0274 Concrete pavement
0275 Segmental pavers - mortar bed
0276 Segmental pavers - sand bed
0277 Pavement ancillaries

3 STRUCTURE

0301 Piling
0311 Concrete formwork
0312 Concrete reinforcement
0313 Concrete post-tensioned
0314 Concrete in situ
0315 Concrete finishes
0316 Precast concrete
0317 Tilt-up concrete
0318 Shotcrete
0321 Monolithic stabilised earth walling
0322 Earth block walling
0323 Straw bale construction
0331 Brick and block construction
0332 Stone masonry
0333 Stone repair
0334 Block construction
0335 Brick construction
0341 Structural steel
0342 Light steel framing
0343 Tensioned membrane structures
0344 Steel - hot dip galvanized coatings
0345 Steel - protective paint coatings
0381 Structural timber
0382 Light timber framing
0383 Flooring and decking

4 ENCLOSURE

0411 Waterproofing - external
0421 Roofing - combined
0422 Roofing - fibre cement
0423 Roofing - profiled sheet metal
0424 Roofing - seamed sheet metal
0425 Roofing - shingles and shakes
0426 Roofing - slate
0427 Roofing - tiles
0431 Cladding - combined
0432 Curtain walls
0433 Stone cladding
0434 Cladding - panels
0435 Cladding - planks
0436 Cladding - profiled sheet metal
0437 Cladding - sheet and pre-assembled systems
0438 Cladding - grc
0451 Windows and glazed doors
0452 Window hardware
0453 Doors and hatches
0454 Overhead doors
0455 Door hardware
0456 Louvre windows
0461 Glazing
0462 Structural glazing
0463 Glass blockwork - combined
0464 Glass blockwork - fire-rated
0465 Glass blockwork - mortar-jointed
0466 Glass blockwork - sealant-jointed
0467 Glass components
0471 Insulation and vapour barriers
0472 Acoustic insulation
0474 Structural fire protection systems

5 INTERIOR

0501 Demolition (Interior and alterations)
0511 Lining
0521 Partitions - systems
0522 Partitions - framed and lined
0523 Partitions - brick and block
0524 Partitions - glazed
0525 Cubicle systems
0526 Terrazzo precast
0527 Room dividers
0531 Suspended ceilings - combined
0532 Suspended ceilings - flush lined
0533 Suspended ceilings - panel systems
0534 Suspended ceilings - tiled
0541 Access floors
0551 Joinery
0552 Metalwork
0553 Stainless steel benching
0554 Stairs, ladders and walkways
0571 Workstations
0572 Miscellaneous furniture
0573 Extinguishers and blankets
0574 Window coverings
0575 Tapestries
0581 Signs and display

6 FINISH

0611 Plastering
0612 Cementitious toppings
0613 Terrazzo in situ
0621 Waterproofing - wet areas
0631 Ceramic tiling
0632 Stone and terrazzo tiling
0641 Applied wall finishes
0651 Resilient finishes
0652 Carpets
0654 Floating panel floors
0655 Applied timber flooring
0656 Floor sanding and finishing
0671 Painting
0672 Wall papering

7 MECHANICAL

0701 Mechanical general requirements
0702 Mechanical design and install
0711 Chillers
0712 Water heating boilers
0713 Cooling towers
0714 Mechanical pumps
0715 Tanks and vessels
0721 Packaged airconditioning
0722 Room airconditioners
0723 Evaporative coolers
0724 Air handling plant - combined
0725 Air handling plant - built up
0726 Air handling plant - minor
0727 Air handling plant - packaged
0731 Fans
0732 Air filters
0733 Air coils
0734 Humidifiers
0741 Ductwork
0744 Ductwork insulation
0745 Attenuators and acoustic louvres
0746 Air grilles
0747 Variable air volume terminals
0751 Mechanical piping
0752 Mechanical piping insulation
0753 Water treatment
0754 Liquid fuels
0755 Medical gas, air and suction
0761 Refrigeration
0771 Automatic controls
0773 Building management systems
0781 Mechanical electrical
0782 Mechanical electrical (minor works)
0784 Motors and starters
0791 Mechanical commissioning
0792 Mechanical maintenance

8 HYDRAULIC

0801 Hydraulic general requirements
0802 Hydraulic design and install
0811 Sanitary fixtures
0812 Tapware
0813 Water heaters
0814 Hydraulic pumps
0821 Stormwater - buildings
0822 Wastewater
0823 Cold and heated water
0824 Fuel gas
0831 Hydrants
0832 Hose reels
0833 Sprinklers

9 ELECTRICAL

0901 Electrical general requirements
0902 Electrical design and install
0911 Cable support and duct systems
0921 Low voltage power systems
0931 Generating sets - stand alone
0941 Switchboards - proprietary
0942 Switchboards - custom-built
0943 Switchboard components
0947 Power factor correction
0948 Uninterruptible power supply
0951 Lighting
0952 Luminaires - custom-built
0961 Telecommunications cabling
0962 Television distribution systems
0963 Home automation systems
0971 Emergency evacuation lighting
0972 Fire detection and alarms
0973 Emergency warning and intercommunication
0979 Lightning protection
0981 Electronic security

APPENDIX B: NATSPEC SHAREHOLDERS

Air Conditioning and Mechanical Contractors' Association of Australia
Association of Consulting Engineers Australia
Australian Council of Building Design Professions
Australian Elevator Association
Australian Institute of Building
Australian Institute of Quantity Surveyors
Building Commission Victoria
Construction Industry Engineering Services Group
Department for Administrative and Information Services (SA)
Department of Finance and Administration
Department of Housing and Works (WA)
Department of Public Works (QLD)
Department of Treasury (ACT)
Department of Treasury and Finance (TAS)
Engineers Australia
Master Builders Australia
NSW Department of Commerce
NT Department of Infrastructure, Planning and Environment
Royal Australian Institute of Architects
Standards Australia

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INDUSTRY DEVELOPMENT

Case Study

OPTIONEER™ – AN INNOVATIVE APPROACH TO CONCEPT DESIGN AND REWORK AVOIDANCE FOR THE WATER INDUSTRY

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ABSTRACT

KBR's vision to develop a tool to improve its traditional concept design process was realised through an internal R&D technology project. During 2004–2005, an R&D team developed a powerful software system that may revolutionise the concept design of water and wastewater infrastructure. The desire to improve concept design processes was twofold. It was not only for the benefit of clients and the offered products and services, but also for improved internal productivity and general sophistication of business practices through using high powered technology. This paper examines the research and development undertaken by KBR to achieve its goals for this exciting new tool.

Known as Optioneer™, the tool prepares concept options for the treatment process, so that for each option the designers, owners, constructors and operators have for their review an intelligent process flow diagram (PFD), an automatically generated 3D visualisation of the plant merged into the site topography, and a relative costing for the various options.

KBR's leading practitioners in the field of treatment plant design developed the tool. The R&D project was broken into a number of distinct phases: initiation, scoping, development, testing and refinement, and rollout. A "gap" analysis was undertaken between tools already available in the software market and the desired "attributes" of the vision. Careful scoping of the project enabled the development process to unfold smoothly.

Keywords: **3D design, option review, water and wastewater treatment, layout, cost, optimisation**

1.0 INTRODUCTION

Kellogg Brown & Root Pty Ltd (KBR) has a history of innovation and technology development for the oil and gas industry, originating from its home base in Houston, Texas. The genesis for the work discussed in this paper was the purchase by KBR of the Australian infrastructure business of Kinhill Pty Ltd and the subsequent realisation that technologies developed for one industry can be appropriately transferred, with adaptation, to another.

In this case, the adaptation focussed on KBR's technology approach to the conceptual design of industrial oil and gas plants, called "3D Conceptual™". The system is a combination of developed Intellectual Property (IP) in the form of proprietary "Intelligent Process Systems", database development of vendor products relevant to the industry and visualisation and collaboration software available commercially. The product enables KBR to offer potential and existing customers worldwide attractive up-front collaborative efficiency.

The availability of the technology led to interest in the application of such a technology for the conceptual design of water and wastewater treatment plants. Experience had shown that the design process could benefit from the same intentions as 3D Conceptual in the industrial area. In particular, the benefits envisaged were:

- early visualisation of the intended design
- early collaboration with owners, constructors and operators with a realistic model of the design
- efficiencies in the design development process with a database of applicable equipment, readily adaptable with parametric design attributes
- rapid concept design quantities and cost estimates.

The purpose of this paper is to discuss the research and development work undertaken towards release of this new tool, called Optioneer™. The tool offers benefits not only for the water and wastewater sector but possibly also for other sectors of the construction industry.

2.0 DEVELOPMENT NEEDS

2.1 IDENTIFICATION OF DIFFERENT INDUSTRY NEEDS

Early scoping of the development requirements identified the major differences that needed to be addressed in moving 3D Conceptual to Optioneer. These are listed below.

- Water treatment plants have a greater proportion of civil works and a lesser proportion of piping. This shifts the balance from auto-routing of orthogonal pipework and introduces needs for new "civil works" parameters.
- Gravity flow is a factor in treatment plants – again scope for development work.
- Topography is important and topographic datasets must be captured, with cut and fill outcomes utilised in option review. Earthworks and roadworks need to be part of the design.
- Brownfield projects are common and impose constraints that the tool will need to take into account.
- The equipment dataset is different.
- A cost estimation database, of course, needs to be developed for the different industry.

2.2 PARENT PROGRAM STRUCTURE

3D Conceptual comprises three main packages: KIPS, Plantwise by Design Power and CADview. Each of these is discussed below.

2.2.1 KIPS

This is KBR proprietary software that allows process engineers to build Process Flow Diagrams (PFDs) in Microsoft Visio and to simultaneously (and automatically) build a database to store design information for the process equipment items. Auxiliary programs produce cost estimates from the database information, produce equipment and line lists, publish database information on the web and export equipment attributes to Plantwise where they are used to construct graphical objects in a 3D CAD environment.

2.2.2 Plantwise

Plantwise is a proprietary software package that is designed for parametric generation of 3D objects in a CAD environment. It is used to construct a 3D conceptual model of a process plant for visualisation and optimisation purposes. Plantwise uses the Microstation graphics engine to display the objects it constructs but has its own tools for manipulating the objects.

Plantwise also has a pipe auto-router that automatically routes pipes between equipment items based on the connectivity defined in the KIPS PFD. The routing is carried out to achieve quasi-optimised layouts i.e. it routes the most expensive pipes first. The router will select routes to avoid obstacles and other pipes and chooses the shortest. Routing is orthogonal only and so is not useful for water and wastewater treatment plant design.

2.2.3 CADview

CADview is a 3D viewer that uses the Plantwise files to build its own 3D model and links the objects to information obtained from the KIPS database. The actual viewer is freeware allowing distribution of the model to project stakeholders who may not have Microstation. The viewer allows the user to move around the virtual site for visualisation of the layout and to view equipment data by double clicking on the 3D object that represents each equipment item.

2.3 WATER AND WASTEWATER REQUIREMENTS

As noted in Section 2.1, water and wastewater treatment plants are made up of a series of tanks that are connected by pipes or channels to allow the main process flows to cascade from one tank to the next by gravity.

The channels are part of the structure so it is only the pipes that need to be routed. These are almost always located under the ground, even if the nozzles on the structures are above ground. There is a minimum cover requirement to the top of pipe and it is desirable the pipe be as shallow as possible, providing the minimum cover is achieved. Typically this would limit the bottom of pipe to 4 m deep or so. On brownfield sites, avoidance of existing buried pipelines is a very time consuming task when pipes are manually routed.

Generally, the pipes are routed by the shortest route to minimise cost and to avoid wasting the available head. This is ”as the crow flies” if possible but subject to modification by the presence of existing structures and underground services. Sometimes pipe corridors are defined by the client and the pipes must be located within their limits.

There are also pumped flow streams but once again the pipelines are usually located below ground and the routing is not necessarily orthogonal.

Pipes are normally sloped but do not have to be consistently sloped and can slope upwards as well as downwards. Pipes run full and do not rely on invert gradient to maintain fluid motion, with this being provided by the water level difference between tanks (or by pumps) on the endpoints.

As well as the underground services, all structures are obstacles. However, structures are often circular in plan and cannot satisfactorily be represented as boxes if non-orthogonal routing is to be fully exploited. Similarly, even rectangular structures are not necessarily aligned with the orthogonal site survey grid.

Electrical cables are also run underground in conduits. These are typically bundled to occupy a rectangular cross-section, the top of which coincides more or less with the ground surface. These could satisfactorily be represented as pipes (particularly since pipes occupy a rectangular prismatic space in Plantwise).

Compatibility with the AutoCAD environment is essential. This is because the industry throughout the world tends to use AutoCAD almost exclusively (and this is client driven).
Recognising the above issues, the following scope was adopted for development of the Optioneer tool:

- CAD environment to be modified to include AutoCAD
- Smart PFD to be expanded to include water and wastewater equipment items
- plant layout optimisation to be included
- pipe routing to be compatible with industry techniques and non-orthogonal
- hydraulic performance to be accounted for in layout optimisation process
- topography to be taken into account in pipe routing and visualisation
- existing infrastructure to be included in plant layout models
- roadworks and associated earthworks to be included
- cost estimation database for water and wastewater projects to be developed and included
- facility for distribution of navigable 3D models to project stakeholders to be included.

3.0 DEVELOPMENT

3.1 PROJECT SCHEDULE

The total project was developed within two years (2004–2005) by KBR's leading practitioners in the field of treatment plant design. The work was done internally for a number of reasons, in particular to bring ownership of the tool to the team. The project involved:

- Phase A – Project initiation, where the project team was established and developed a first cut functional specification
- Phase B – The Scoping Phase, where the specialists in the team investigated and understood the practicality of the vision and the challenges and scoped the required development work. A "gap" analysis was undertaken between tools already available in the software market and the desired "attributes" of Optioneer
- Phase C – Project development, where the program was developed to meet the requirements of both the functional and detailed specifications

- Phase D – Testing and refinement, where the system was tested on actual projects and refinements undertaken
- Phase E – Ownership and rollout.

Principal technical challenges were related to the inclusion of earthworks as a necessary component of the system, the database development for all of the plant and equipment and the development of a total cost estimation database. However, all phases were completed to plan and within budget.

3.2 NEW PROGRAM MODULES

Modules developed for the system included:

- Equipment Builder (to handle various equipment types)
- Pipe Router (not automatic initially but able to perform tasks of a “pipe router”)
- Earthworks Manager
- Road Builder

3.2.1 Equipment Builder

An equipment builder was developed to store 3D Autocad equipment items, corresponding to those equipment items developed in KIPS. The syntax for the equipment items also allows translation to other CAD environments (e.g. Microstation Plantwise). Parametrics driving the smarts behind the objects enable rapid resizing and movement of objects at the click of a button, minimising the need for re-design as concept designs evolve.

3.2.2 Pipe Router

The pipe router is semi-automatic and more compatible with industry practice. It requires a manual line to be drawn initially in plan to indicate a proposed connection route between two structures. Other commercially available pipe routers use a similar philosophy. The router then automatically constructs the physical pipeline elements around the line, creating the visual pipe “building” process. The router also develops automatically a longitudinal section of the pipeline, considering terrain and clashes with existing services in considerably less time than that taken manually, with a report and visualisation of the piping details generated as required.

3.2.3 Earthworks Manager

Existing topography, construction earthworks and final earthworks surfaces are considered using Triangular Irregular Networks (TINs) and grid patterns. The engine automatically cuts proposed plant and equipment into the topography and calculates cut and fill quantities as output and gives visual representation of the surfaces.

3.2.4 Road Builder

A roadworks tool considers new roadways within the plant and in relation to the position of equipment structures and earthworks. The tool enables rapid visualisation of roads including intersection points, and similarly automatically generates quantities and costing contributions.

3.3 TESTING AND OUTPUTS

Pilot testing of the system was undertaken during Phase D (testing and refinement) on a number of projects involving different types of plant and processes. The results successfully proved correlation with known data. Pilot testing techniques were also used throughout the development work in Phase C to ensure the desired functionality could be developed and achieved. Gaining this confidence early enabled the team to achieve double the rate of progress during development compared with plan.

The tool is now moving steadily and rapidly into business practice following successful completion of pilot trials on a number of KBR's water and wastewater treatment plant projects.

Sample images from Optioneer are provided in Figures 1 and 2:

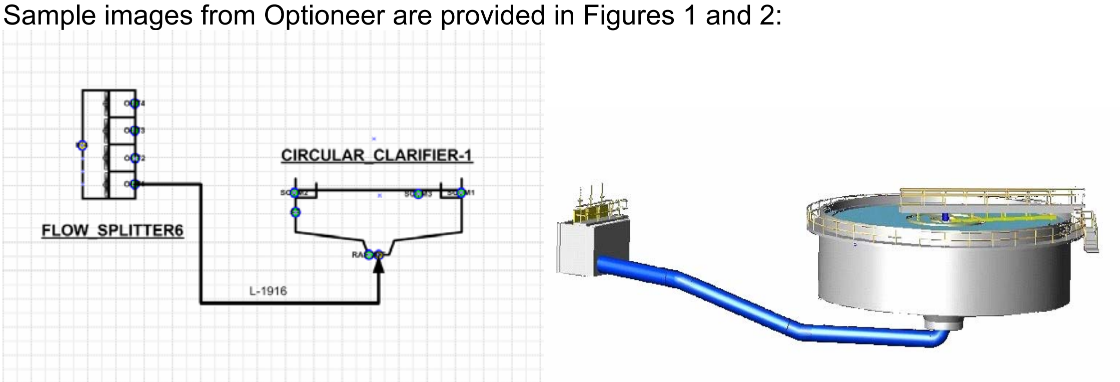

Figure 1 Optioneer PFD and 3D image for flow splitter and clarifier

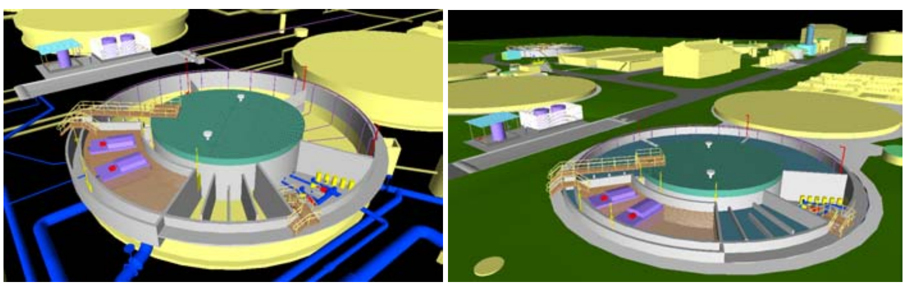

Figure 2 3D concept testing as part of a specific wastewater treatment plant example

4.0 CONCLUSION – A NEW PRODUCT FOR THE CONSTRUCTION INDUSTRY

3D concept design tools of this nature have the potential to revolutionise the concept design of water and wastewater infrastructure. Importantly the capacity of the tool involves far more than just 3D images.

The use of the intelligent process schematic, linked to a unit process database, provides a new design tool for the process engineers as well as a cost estimation database and a drafting model. The result is the "virtual" design and costing of a wastewater asset, on greenfield or brownfield topography, all at the preliminary concept design phase. Such a tool allows owners, constructors and operators to collaborate very early in the design process to test and visualise any number of options for water and wastewater treatment facilities.

The relative costing of each option is of course a constant reference in the review process. The software produces a fly-through of alternative layouts, automatically calculating material quantities and capital/operating costs, and allowing the optimum configuration to be selected and avoiding the need for expensive rework later. Such costings include consideration of long-term operations and whole-of-life costs before committing to detailed design.

In summary, the specific modules of Optioneer facilitate a range of design process innovations, which include:

- On-screen construction – Process flow diagrams (PFDs) can be rapidly constructed on screen from template icons for more than 100 pieces of plant and equipment
- Automatic sizing and shaping – Smart data associated with the PFD icons automatically convey dimensions and shape to the 3D images
- Easy equipment placement – Each piece of equipment can be "dragged" and located into the 3D environment
- Automatic calculations – The process of cutting 3D shapes and sizes into the 3D topography is automatic, as is the calculation of cut and fill volumes for preliminary construction and final trim earthworks surfaces
- Efficient pipeline configuration – Pipeline connections in the PFD become 3D images located in plan and dragged in elevation to an appropriate grade-line, avoiding clashes with existing pipes
- Streamlined road planning – Road images are automatically constructed from "smart box" information with cut and fill volumes automatically determined
- Updated costings – Historical data on costings provide the basis of automatic updates on overall equipment, pipeline, roadworks and earthworks costs for each option.

Layouts can be optimised based on topographic, process and cost factors, saving precious time and rework later. Concept options can be readily communicated to all interested parties and collaborative concept option engineering can occur. Risk assessment is enhanced by the visual representation. And all concept options can be quickly compared on the basis of operator management, capital cost and whole of life cost.

Such a system, targeting visualisation innovation for the construction industry, is less amenable to a written paper. Nevertheless, it is anticipated that its development offers a high level of interest for this specific sector and potentially other sectors of the construction industry.

MEETING CLIENT NEEDS

Refereed paper

CASE STUDIES ON IMPLEMENTATION OF CONSTRUCTABILITY IMPROVEMENT BY CONSTRUCTION PROJECT OWNERS IN INDONESIA

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ABSTRACT

Constructability is an approach that links the design and construction processes, which can lead to significant savings in both cost and time required for completing construction projects. Improving constructability of construction projects is the responsibility of all project stakeholders: owners, designers and contractors. The owners have the most authority in enforcing implementation of constructability, therefore their role in constructability improvement of construction projects is the most important. Project owners must be aware that the decisions that are made in the initial stages of planning and design are difficult and costly to change once construction begins. This paper describes a study how construction project owners integrate construction knowledge and experience into planning and design in existing practice; and their role in improving constructability. The methodology chosen to find the answers to these questions was to use case studies. Interviews, conducted using structured questions, were used as the main method of data collection in the case studies. The study shows that project owners in Indonesia do have some understanding of the importance of constructability. The method of constructability input is determined by the project owners' selection of project delivery approaches. Any project stakeholders can provide constructability inputs. However, involving contractor personnel early in the project can identify major problems that may be encountered during the construction phase and leads to the greatest improvements in project performance.

Keywords: Constructability, project owners, integration

1.0 INTRODUCTION

1.1 THE CONSTRUCTION INDUSTRY IN INDONESIA

The construction industry in Indonesia is relatively young. However, it has grown significantly since the early 1970s. Its contribution to GDP increased from 3.86% in 1973 to above 8% in 1997. It constituted about 60% of gross fixed capital formation. The number of people has increased significantly, from 413,000 in 1978 to about 4.2 million in 1997. Although it experienced a contraction of almost 40% in 1998, due to the economic crisis in the country, it has started to grow again since then. Many construction projects are awarded on a competitive basis using the traditional approach. In this approach, professional designers and constructors are engaged in separate contracts. The contractors are usually not involved until the designs have been completed. The separation of design from production in the construction process has led to a certain amount of isolation of the professionals from technical development in construction industry (Wells 1986). This division has also been suggested as being responsible for the lack of constructability of the construction projects (Griffith 1984), which was cited as a reason for projects exceeding budgets and schedule deadlines (Construction Industry Institute Australia 1992). By separating construction from design the function project stakeholders are ignoring opportunities of significant savings in project cost and completion time resulting from the careful interaction of planning, design, and engineering with construction (Tatum, Vanegas et al. 1986).

1.2 CONSTRUCTABILITY DEFINED

The concept of constructability in the US and the equivalent concept of buildability in the UK emerged in the late 1970s. It evolved from studies into how improvement can be achieved to increase cost efficiency and quality in the construction industry. It is an approach that links the design and construction processes. In this paper constructability is defined as 'the optimum use of construction knowledge and experience in planning, design, procurement, and field operations to achieve the overall project objectives' (Construction Industry Institute 1986). It emphasizes the ability to construct and the importance of construction input to all project phases. The Construction Industry Institute (CII) in the US has developed Constructability Concepts to stimulate thinking about constructability and how to make it work. The CII has also shown benefits of implementing constructability, especially in terms of project cost and schedule. In implementing improvement in constructability, the study by the Australian Construction Industry Institute (Francis and Sidwell 1996) suggests that it is important to consider the uniqueness of the construction industry in a specific country.

Improving constructability of construction projects is the responsibility of all project stakeholders: owners, designers and contractors. However, as the owners have the most authority in enforcing the implementation of constructability, the owners' awareness of the benefit of improved constructability is the most important. Construction project stakeholders, especially owners, must be aware that the decisions which are made in the initial stages of planning and design are difficult and costly to change once construction begins. This paper describes a study of construction project owners in Indonesia which explorer their current constructability practices and its impact on the project performance. This study was conducted using a questionnaire survey.

2.0 DESCRIPTION OF THE CASE STUDIES

2.1 PROJECT DEVELOPMENT FOR 'JABOTABEK' RAILWAY FACILITIES (CASE STUDY A)

In Indonesia, the Department of Transportation is responsible for the development of transportation infrastructure such as ports and railway as well as their related facilities. As part of the railway infrastructure development in the Jakarta-Bogor-Tangerang-Bekasi (Jabotabek) area, the Department of Transportation has set up a project management group responsible for managing that project from conceptual planning to completion. This organisation reports to the Director General of Land Transportation under the Ministry of Transportation.

The main function of this organisation is to coordinate the railway infrastructure development for public transportation within the nation capital, Jakarta, and its regional area, ie Bogor, Tangerang, Bekasi (Botabek). It has the following tasks:

- Prepare the program and planning for an integrated Jabotabek railway system in accordance with the government master plan for railway infrastructure development;
- Prepare the engineering design for construction, the terms of reference for consultancy services, and the engineering specifications for materials and equipment;
- Prepare the pre-operation planning, which includes human resources training and development, for a modern and reliable railway system;
- Execute the program and development planning for the integrated Jabotabek railway system.

The Jabotabek railway development project is a multi-year project, commenced in 1997 and scheduled to be completed in the year 2005. The estimated total project cost is Rp. 1634 billions, with the detailed project components as follows:

- Railway track and crossing 9.7%
- Signalling system improvement 31.2%
- Electrification 9.3%
- Railway station improvement 8.6%
- Depot and workshop 1.9%
- Double tracking 3.8%
- Elevated railway 25.8%
- Train procurement 5.8%
- Others 3.9%

Each project component is to be bid and awarded in separate contracts. The interview was conducted with the project manager for one of the project components, the construction of the rain operation control system of the western and eastern lines.

The main funding for the project comes from the OECF, Japan, which is providing 73.6% of the total project cost. The other overseas funding is from the France Protocol, which is contributing 12.5%. The Indonesian government is to contribute the other 13.9%. As is typical for public sector projects, this project is using the traditional approach where the construction contractor is not involved until the design is completed.

2.2 SEPINGGAN AIRPORT PROJECT DEVELOPMENT (CASE STUDY B)

As described earlier in this section, the Department of Transportation is responsible for the development of transportation infrastructure such as ports and railways as well as their related facilities. The Sub-directorate for Airport Engineering under the Directorate General of Air Transportation is responsible for coordinating airport facility development, including the development of Sepinggan International Airport in Balikpapan, East Kalimantan. As the project owner representative, this sub-directorate is responsible for the management of the project from its conception to completion. A project team was established to manage the delivery of the project.

The interview was conducted with the Head of the Sub-directorate for Airport Engineering. Therefore, the information obtained covers only general issues on constructability at the company level.

2.3 16KM FUEL PIPELINE - KALTIM PRIMA COAL (CASE STUDY C)

PT. Kaltim Prima Coal (KPC) is a multinational mining company operating in Sangatta, East Kalimantan. Typical projects that KPC builds are heavy engineering/infrastructure projects for mining operations. As the mine is already in operation, most of the current construction works are relatively small both in size and value. For the year 2000, the estimated construction project value is only US$ 1.5 million, with the typical size of individual projects being between US$ 50,000 and US$ 100,000.

One of the construction projects that was completed by KPC as part of the development of its facilities was a 16km fuel pipeline. This project was delivered using a design-construction approach, and was awarded to the main contractor using a lump-sum contract. The contract value was US$ 2.1 million, and scheduled construction time was 9 months. The interview was conducted with the contract mining manager.

3.0 CONSTRUCTABILITY ISSUES

3.1 EXISTING CONSTRUCTABILITY EFFORTS

Most of the respondents were not familiar with constructability as a concept as described by CII or CIIA. However, in delivering their projects they had actually performed some constructability activities. Table 1 summarises the constructability efforts of the respondents.

In the public sector, many construction projects are delivered using the traditional approach. In this approach, constructability or general construction inputs are provided by in-house personnel or by consultant personnel. In the case of the Jabotabek railway development project, a constructability review was part of the project management consultant's scope. The project management consultant also acts as the constructability coordinator and carries out constructability orientation for the other project team members. They report to the Project Manager. The Head of the Sub-directorate for Railway Construction can be categorised as the executive sponsor for implementation of constructability. Constructability is usually treated in combination with other project activities such as value engineering. Reviews of constructability issues are also included in the monthly project team meeting. This program or procedure for constructability is implemented on all project components.

Another approach to improve constructability in the public sector projects is by setting up a technical team to assist project managers with engineering and construction matters. This team typically is appointed by the related department or directorate general. In the case of the Sepinggan airport project, which is under the Department of Transportation, the technical team was appointed by and reports to the Director General for Air Transportation. The director general can be defined as the executive sponsor for the implementation of constructability. The technical team consists of experienced construction personnel from the Department of Transportation and the user, in this case a state-owned company that manages the operation of the airport. The team acts as the constructability coordinator and is responsible for providing construction input in all phases of the project. The consultation between the project team and the technical team is reported in the weekly and monthly progress reports. At the completion of the project lessons learned during its execution are recorded and reported in the project final report. The technical team performs constructability reviews in most projects, especially those funded by foreign loans, as most of them are multi-year projects and require good coordination with many other institutions. This is typically performed in combination with other project activities such as value engineering. However, it is not common to appoint a technical team for projects that are funded purely through government budgets.

Table 1 Constructability efforts

	Case Study A	Case Study B	Case Study C
General constructability effort	- Constructability review is included as the scope of Project Management consultant	- A technical team appointed by the department to assist the project team for all engineering and construction matters. - Lessons-learned from the project are recorded for future projects	- Constructability as part of the risk assessment program - More focus on safety than on cost savings - It is more exception than the rule
Implementation of constructability	- Combined with other programs such as value engineering - Included in owner reviews during monthly project team meeting - Contractor feedback - Implemented to all project components	- Combined with other programs such as value engineering - Included in owners' project report - Contractor feedback - Implemented on most projects funded by overseas loans - Not common on projects funded through government annual budget	- Combined with other programs such as value engineering - Depends solely on the person responsible for the project - Contractor feedback
Constructability sponsor	Head of Directorate for Railway Transportation	Director General for Air Transportation	None
Constructability coordinator	Project management consultant for the duration of the project	Technical team for the duration of the project	None

At KPC, constructability is approached as part of the risk assessment for construction during the planning stage. It is more a safety approach, although cost savings are also achieved. However, its implementation depends solely on the person responsible for the project, and it is more the exception than the rule. In the implementation, constructability is treated in combination with other project activities such as value engineering. There is no constructability program either at the company level or at the project level.

3.2 SOME CONSTRUCTABILITY ISSUES

Typical constructability issues that have been identified by the respondents are summarised in Table2.

Table 2 Some constructability issues identified in the interviews

Project respondent	Case Study A	Case Study B	Case Study C
Periodic reviews of specifications	Yes, for selected projects	Yes	No
Communicate lessons-learned from previous projects	-Not in all projects. -Done through project coordination meeting	Included in project final report	Through project management training
Improving design to aid construction practices	-Joint review by consultant, owner and user -Adjustment to field condition	Construction feedback	-
Works that are standardised or done repeatedly	Most of the works	Airport layout	-
Problems with dimensional tolerances	-	Material dimension problems due to the lack of local sources	-
Reduce physical interference	-	Use pre-fabrication system	-
Area where pre-assembly can simplify construction	-	- Hanger construction - Drainage pipe - Steel bridges - Pile foundations	-
Constraints for timely flow of information	Coordination with other institutions	Communication problems due to language barriers	-
Improvement in procurement	-	Identify local sources for construction material	-
Major sources of reworks	-	- Lack of skilled labour - unpredictable weather condition	-
Innovative construction techniques employed	-	Use of micro-piles to strengthen existing column	-
Area to implement labour-intensive method	railway construction	- landscaping - excavation	-

All companies included in the case studies have maintained lessons learned from completed projects. These lessons learned were usually included in the project final report, and they were communicated to other company's staff through project meeting, project management training and project presentation. Web based database has also been used to maintain and communicate lessons learned.

Periodic reviews of specification were done by most of the respondents in the case studies. At PT. Kaltim Prima Coal, the constructability approach was more the exception than the rule. Therefore there is no specific effort in improving constructability on their projects. Improving design to aid construction practices was also done for improving constructability. One of the case studies respondents has used a computer-added design (CAD) software to improve constructability of its design. Other common activities that have been done in an effort to improve constructability of their projects were standardisation of some construction works, improvement in procurement, use of innovative construction technique and implement labour-intensive methods. Labour intensive methods usually were used for works that are big in volume but do not require high skill. The works are performed on the ground and are usually not related to architectural finishing. Some examples of the works that are done using labour intensive methods include railway construction, sewer construction, paving block installation, ground reservoir construction and septic tank construction.

Coordination and communication problems, particularly during planning and design phases, were common constraints for timely flow of information from design to the field. Designers in different engineering disciplines are concerned only with their own area, and almost always coordination is poor. It is not uncommon to find discrepancies during the construction period. As a result some works have to be stopped until a solution is found/agreed. This has also been identified as one of the sources of reworks. Other sources of reworks were inconsistency in the performance of construction personnel or lack of skilled labour.

4.0 IMPROVING PROJECT CONSTRUCTABILITY

As explained in the description of the case studies, the interview on the Sepinggan airport project case study was conducted with the Head of the Sub-directorate for Airport Engineering. Therefore, this case study is not included in the review of constructability improvement at the project level.

This section discusses implementation of improvement in constructability at the project level. It begins with a discussion on participation of project stakeholders in constructability activities. This is followed by discussions on implementation of constructability in planning, design, and procurement as well as construction phases of the project.

4.1 PARTICIPATION IN CONSTRUCTABILITY ACTIVITIES

The traditional approach, which is the typical project delivery method for the public sector, limits the involvement of contractor personnel in the pre-construction phases. In this case, constructability inputs are provided by project management consultants or by a technical team appointed by a related department. The design-construct and design-manage approaches enable contractor personnel to be involved in the pre-construction phases and to provide input to constructability.

In the Jabotabek railway development project constructability is initiated in the conceptual planning phase, particularly when evaluating the feasibility of individual projects. About 50% of the project team meeting during the conceptual planning phase as well as during the design phase included discussion of constructability issues. Experienced construction personnel were employed, through the project management consultant, to provide advice on the feasibility of project budget and schedule as well as evaluating the conceptual project layout. In addition, a team of experts appointed by the Department of Transportation is also involved in evaluating these issues. They all report directly to the project manager.

In the construction of the 16km fuel pipeline, KPC initiated constructability during the conceptual planning phase. About 60% of the project team meeting during this phase included discussion of constructability issues. During the design phase about 50% of team meetings included discussion on constructability. About 10% of the project team meeting was devoted to constructability. The construction contractor was engaged to provide construction input as early as the conceptual planning phase. Other sources of constructability inputs were the owner's representative and the design consultant. Experienced construction personnel from within the company were involved in providing input on the feasibility of the project budget and schedule as well as the conceptual project layout. They reported to the project sponsor.

4.2 IMPLEMENTATION OF CONSTRUCTABILITY

During conceptual planning all respondents stated that in developing their project execution plan they included constructability, and that the project schedules were construction sensitive. All respondents considered various external factors, eg site conditions, financial policy, socio-political influences, political influences, and environment in their project planning. Other constructability activities that all respondents performed in their projects were giving consideration to pre-assembly/pre-fabrication and using construction input to develop conceptual site layout.

Constructability activities that were performed by three of the four respondents were considering major construction methods in developing basic design approaches and using construction input to develop a risk management plan. The main construction method was not considered in developing the basic design approach for the project components included in the case study of the Jabotabek railway project.

In the Jabotabek railways project and the KPC 16-km fuel pipeline project, early construction input was not used in formulating contracting strategy. In the Jabotabek railway project, early construction inputs were used to assess labour capabilities.

During the design phase, 3D-CAD has not yet been used in any of the projects in an effort to avoid physical interference, and no constructability consultant was engaged in the projects. As described in the previous section, either in-house construction personnel or the main contractor provided constructability inputs. In designing the 16km fuel pipeline, KPC made safe construction a priority in the project design.

The respondents were also asked about how they procured the construction works as well as major equipment. Those issues include: preparing the work packaging; considering schedule effectiveness of past projects in selecting vendors or subcontractors; identifying critical pieces of equipment on drawings and vendor data that should be monitored closely; consulting constructor to determine any equipment requiring special rigging procedures and/or additional cranes; having major vendors participate in the constructability effort; and considering local content requirement for materials and equipment. Most respondents responded yes to all questions except the participation of major vendors in the constructability effort.

As the Jabotabek railway project delivered using the traditional approach, the design was 100% completed at the time the construction contract was awarded. The other project was delivered using the design-construct approach, where the project design was still progressing when the construction works were awarded. Informal constructability plan reviews were performed in all projects in the case studies. In these reviews, appropriate lessons-learned from previous projects were also evaluated. In the Jabotabek railway project, the reviews were conducted monthly during the design-procurement phase by the project management consultant. In the KPC 16km fuel pipeline, the constructability plan reviews involved riggers, construction supervisors and the project manager.

The traditional approach to the project delivery in the Jabotabek railway project prevented the owner and designer from obtaining constructor input in the design. In the other project, the constructor was consulted to provide construction input in the design. By integrating the contractor's input, the construction activities are better understood by the construction supervisors as well as the labour force. This condition leads to better project performance, as the construction operation becomes more efficient and potential reworks can be identified and avoided.

When asked about innovative construction methods, the respondents mostly referred to pre-assembly or pre-fabrication methods in construction. Labour-intensive methods were used in some parts of the projects in all the case studies. In the Jabotabek railway project, labour-intensive methods were used particularly for project components that had railway construction component. KPC used non-skilled labour for repetitive jobs and trained the labour force to do these jobs. Supervision training for sub-contractors' foremen was conducted for this method of construction.

4.3 PROJECT PERFORMANCE

To measure the performance of the projects included in the case studies, the respondents were asked whether they encountered any of the construction problems. One of the project components of the Jabotabek railway project (A) included in this case study was the construction of train operation control systems for the western and eastern line, and establishment of a train dispatching system. The main constructability problem encountered in this project was the untimely delivery of engineering documents, especially when involving other government institutions. Another problem that was faced during the construction period was the problem with physical interferences. However, this problem was considered minor. In the 16km-fuel pipeline project (C) built by KPC, the only significant difficulty encountered during the construction period was with the nominated sub-contractor.

The construction of the train operation control system of the western and eastern lines, and establishment of a train dispatching system project component of the Jabotabek railway project was completed within the initial schedule and budget. The full knowledge of the scope of project may have contributed to this performance. However, project safety was considered low. About 2% of the total construction cost was spent on changes/reworks, and unanticipated field engineering or design support was about 5% of total design man-hours. The 16-km fuel pipeline project was completed within the contract value of US$ 2.1 million and within the 9-month schedule. The safety record for this project was considered above average. The percentage of the total construction cost spent on changes/rework was about 1%.

The most common barriers to constructability encountered in these case studies were poor appreciation of the importance of constructability and the lack of qualified personnel. Another common barrier was the coordination during the planning and design phases.

5.0 CONCLUSIONS

Improvement in constructability has been implemented informally by different construction project stakeholders in Indonesia, as part of other project or construction management activities such as value engineering, project quality plans and risk assessment programs. Constructability is initiated as early as the conceptual planning phase by including discussion on constructability issues in the project team meeting. At project completion, lessons-learned from the projects are usually included in the project final report. Those lessons-learned are used as reference for future projects. Project coordination meetings and project management training are the methods that have been used to communicate these lessons learned.

Improving constructability of the projects can lead to considerable savings in both project cost and time as well as improvement in project quality and safety. However, there are some barriers in implementing improvement in constructability, particularly lack of awareness or appreciation of constructability issues and lack of qualified personnel.

The method of constructability input is determined by the project owners' selection of project delivery approaches. Any project stakeholders can provide constructability inputs. However, involving contractor personnel early in the project can identify major problems that may be encountered during the construction phase and leads to the greatest improvements in project performance.

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MEETING CLIENT NEEDS

Case Study

HVAC SYSTEM SIZE – GETTING IT RIGHT

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ABSTRACT

There is evidence that many heating, ventilating & air conditioning (HVAC) systems, installed in larger buildings, have more capacity than is ever required to keep the occupants comfortable. This paper explores the reasons why this can occur, by examining a typical brief/design/documentation process.

Over-sized HVAC systems cost more to install and operate and may not be able to control thermal comfort as well as a "right-sized" system. These impacts are evaluated, where data exists.

Finally, some suggestions are developed to minimise both the extent of, and the negative impacts of, HVAC system over-sizing, for example:

- Challenge "rules of thumb" and/or brief requirements which may be out of date.
- Conduct an accurate load estimate, using AIRAH design data, specific to project location, and then resist the temptation to apply "safety factors
- Use a load estimation program that accounts for thermal storage and diversification of peak loads for each zone and air handling system.
- Select chiller sizes and staged or variable speed pumps and fans to ensure good part load performance.
- Allow for unknown future tenancies by designing flexibility into the system, not by over-sizing. For example, generous sizing of distribution pipework and ductwork will allow available capacity to be redistributed.
- Provide an auxiliary tenant condenser water loop to handle high load areas.
- Consider using an Integrated Design Process, build an integrated load and energy use simulation model and test different operational scenarios
- Use comprehensive Life Cycle Cost analysis for selection of the most optimal design solutions.

This paper is an interim report on the findings of CRC-CI project 2002-051-B, Right-Sizing HVAC Systems, which is due for completion in January 2006.

Keywords: Size, Over-sized, HVAC, capacity, impacts

1.0 HVAC SYSTEM SIZE – GETTING IT RIGHT

1.1 DEFINITION

What do we mean by “correctly sized HVAC system”? We would say that if you examined an annual log of system cooling loads, you would see some occurrences in the 90 to 100% range.

For comfort cooling applications, standard design practice uses the concept of design day – conditions that are exceeded, on average, on 10 days per year. Thus on these ten days, you would expect to find the HVAC system fully loaded. Cooling systems can also operate fully loaded when removing heat built up after a hot weekend. However, these situations are eased somewhat by the diversity that is likely to occur in other loads, such as occupancy, equipment etc – i.e. some people will be on leave, sick etc, and not every area will have its entire allocation of equipment installed or operating.

If a HVAC system is undersized, there will be more hours per year when the plant is running fully loaded, and the system will not be able to hold indoor design conditions even on a “design day”, let alone any hotter days; i.e. space temperatures will rise.

If a HVAC system is over-sized, it never runs fully loaded – a log of system loads may never reach 80 or 90%. Over-sized packaged plant will tend to “short-cycle” and is unlikely to control humidity well.

However there are a few conditions that must be imposed before this definition is adequate:

- The system components and controls must have been correctly designed and commissioned. If chilled water system flow-rates are lower than designed, the chiller set will never be fully loaded. Cooling loads can also be reduced if outside air rates are low or if space temperatures are not controlled within the comfort range.
- The building must be fully occupied.
- False loading of heating and cooling systems must not be occurring, i.e. if heating is fighting cooling, due to dampers or valves leaking, the chiller plant may be artificially loaded, giving the impression of correct sizing.
- Spare capacity, intentionally included in the design, must be excluded from the analysis. This spare capacity provides redundancy to cover breakdowns or an allowance for future increased tenant loads.

The remainder of this paper is about unintentional over-sizing of HVAC systems, i.e. provision of more capacity than is required to meet the design brief.

1.2 EVIDENCE OF OVER-SIZING

Surveys have shown that HVAC over-sizing is common in the UK:

Knight and Dunn (2004) report on a study of over 30 air conditioning systems in office buildings in Wales: “Analysis of the part-load chiller energy consumption profiles…revealed that virtually all the systems were oversized for the loads they actually encountered in practice.”

Crozier (2000) reports a survey of 50 HVAC systems in the UK, which showed that 80% of the heating plant, 88% of the ventilation plant and 100% of the chiller plant incorporated capacity above that needed to meet design requirements. See Fig. 1.

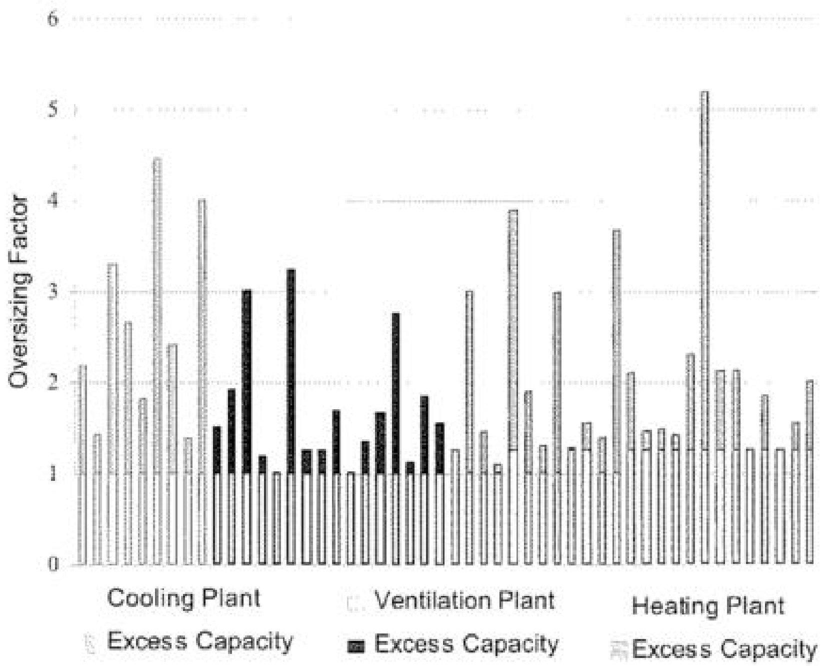

Figure 1. Summary of oversizing in 50 HVAC systems. [Crozier]

Deng (2002) presents a case study from Hong Kong, where the original design included four 2000kW chillers (total 8,000 kW) but operating records showed that the highest cooling load recorded was 3,516kW.

1.3 PROCESSES THAT LEAD TO OVER-SIZING

Knight and Dunn (2004) conclude that high design guide values for estimating internal heat gains (occupancy, lighting and equipment) are one important reason why commercial HVAC systems are being oversized. These values are based on high occupancy levels (persons/m²), which are rarely reached.

1.3.1 Occupancy loads

Traditionally, design loads for occupancy in office buildings are set at 10 m^2/person. A report by the various state governments (GREG 2000) reveals that the internal targets for NLA per "full time equivalent" employee ranged from 15 m^2 to 18 m^2. Actual numbers were even higher, ranging from 17.6 m^2 to 21.2 m^2 (Tasmania had an unrepresentative value of 26 m^2, due to having a high percentage of heritage-listed buildings with inefficient space utilisation). From this report is seems that government offices may be designed for occupancies that are 50% to 100% larger than required. There may be some automatic application of the default figure of 10 m²/person, required by AS1668 for calculating fresh air requirements when occupancy is unknown, to calculation of heat gain from occupants. There is no reason why the same figure should be used for both.

1.3.2 Internal loads

The Property Council of Australia (PCA) has developed a grading matrix for office buildings that is the benchmark for space quality in the Australian real estate industry. This matrix quotes internal load capability for a "premium grade" building to be **more than** 25 W/m^2. This type of grading encourages "chest beating" exercises within the real estate industry, with each property manager trumpeting higher and higher internal load capabilities. Anecdotal reports of property managers advertising internal load capabilities of 40 W/m^2 have been heard by the authors.

Anecdotal reports seem to suggest that in the Australian real estate market place activities in the top end of the market are moving in two divergent directions. In general open-plan office space, there seems to be evidence of the internal load reducing. This is due to uptake of much more efficient LCD monitors that also offer other advantages in glare and contrast performance. Many employers are providing employees with laptops, and requiring them to take them home. Both these actions would tend to reduce internal loads, because the equipment is much more efficient and is not left on overnight. Komor (1997) reported measured loads from office equipment in 44 buildings in the USA. The simple average was 8.9 W/m² and the highest value was 12 W/m².

However, there is greater requirement for areas dedicated to IT, which house servers and other high power equipment in a confined space due to security requirements. These areas require 24-hour cooling and are usually conditioned by additional supplementary HVAC systems supplied by a dedicated tenant condenser water system. These internal loads should not be accounted for in calculating the size of the base building chilled water system.

1.3.3 Temperature setpoints

Close control of internal temperatures, for example, 22.5°C±1°C, is difficult to maintain in practice and can lead to excess capacity and higher energy use. The energy efficiency provisions proposed for the new Section-J of the BCA (2005) will require HVAC systems to be designed to maintain a temperature range between 20°C and 24°C for 98% of the system operating time. Such wider thermostat settings can improve stability of operation due to a larger "dead-band" provision, and also result in a smaller system capacity requirement.

1.3.4 Discrete design process

Concept designs can be carried out independently by project team players. For example, an HVAC designer may use overly conservative glazing characteristics very early in the project and develop high cooling load estimates. If these are not revised further down the track, for whatever reason, e.g. paucity of time or budget, there is good chance that the HVAC system will be oversized.

An interactive approach to design where all major energy sub-systems are reviewed together would lead to optimised façade, electric lighting and HVAC systems.

1.3.5 Conservative design approach

A number of factors can be approached from a conservative stance. If these factors are independently added together, the result could be a system that is significantly oversized. Some of these factors are :

Overshadowing

Not considering the impact of surrounding buildings when doing the cooling load calculations can have a significant impact on peak demand. This path is sometimes taken because the client or engineer takes the view that buildings around the project may be demolished at some later date. If so, there would be a significant increase in cooling load on the project until an equivalent structure was re-built.

Unknown tenants

Most buildings in Australia are speculative in nature. Tenant requirements are unknown till late in the project when a real estate agent is successful in finding an anchor tenant. The PCA grading matrix recommendation provides minimum internal load capability, and the "chest beating" exercises in the market place encourage larger rather than smaller internal loads.

Contractual obligations

A correctly designed system will in fact not maintain temperatures on the worst hours of the year, when conditions go beyond the "design day" and other internal loads are at high levels. Engineers are conscious of the fact that building use changes frequently, and design their HVAC systems to be able to cope with such changes by over-sizing. Design fees for engineers are based on competitive tender, and do not generally allow for iterative or integrated design solutions. Ultimately, engineers feel their reputations would suffer should a building HVAC system fail to maintain temperatures.

There is also the "split-incentive" that was identified as one of the major reasons for the government to propose a mandatory regulation of energy efficiency. This is the fact that the developer does not generally reap the economic benefits of an energy efficient, lower greenhouse impact design, since he/she does not normally own and operate the building. Given two alternate design solutions, the developer will pick the least-cost solution.

"Design and Construct" contracts also encourage oversizing. The contractor tenders on a rough design load that is to be confirmed before construction. The competitive tender situation under which these jobs are won means that there is little incentive to review and optimise design calculations.

This type of risk-averse, aggressive, commercial environment encourages oversizing by using a "worst case" approach as a convenient, no-hassle solution to these issues. Unfortunately it is society that is penalised in the longer term.

1.4 IMPACTS OF OVER-SIZING

Oversizing of HVAC plant has a flow-on effect through the project. Oversized chillers will also require bigger pumps, pipes, cooling towers, valves etc., and also a larger plant room. Chiller plant is usually available in discrete "frame" sizes. Oversizing to a degree where the plant selection requires purchase of the next frame size can increase the absolute cost of the bigger chiller substantially, although the cost per kW may actually decrease.

Oversized air-handling plant will also require larger fans, ducts and riser sizes. Oversized HVAC systems in larger projects may also lead to poor thermal comfort in the conditioned spaces, as the plant may not be able to turn down enough to provide stable operation and may lead to poor air distribution as cold air "dumps" from diffusers at low flows, instead of flowing along the ceiling.

Oversized equipment can also impose a penalty in terms of peak demand charges for electricity, as the larger motors would draw higher currents when loaded. The impacts can flow through the energy supply chain with thicker cables, larger switchboards and sub-stations. Other impacts as listed by Hourahan (below) also apply to the larger systems.

Hourahan [2004] lists the effects of over-sizing of unitary air conditioning systems, which are typically found in residential and small commercial buildings:

- Marginal part-load temperature control
- Large temperature differences between rooms
- Degraded humidity control
- Drafts and noise
- Occupant discomfort and dissatisfaction
- Larger ducts installed
- Increased electrical circuit sizing
- Excessive low-load operation
- Frequent cycling (loading/unloading)
- Shorter equipment life

- Nuisance service calls
- Higher installed costs
- Increased operating expense
- Increased installed load on the public utility system
- Increased potential for mould growth
- Potential to contribute to asthma and other respiratory conditions.

Proctor, Katsnelson and Wilson [1996] explain why air conditioners that cycle ON/OFF to control temperature are less efficient when they are oversized. Air conditioners are very inefficient when they first start, only reaching peak efficiency after about 10 minutes of operation. An oversized air conditioner will cool the space quicker and may often operate in this inefficient "zone". They estimate that if an air conditioner is double the required size the energy consumption would increase by 10%.

Crozier [2000], estimates that over-sized plant is "responsible for approximately 10-15% of HVAC related energy consumption" in U.K.: "Oversized air handling systems and components can incur increased space requirement, capital costs and energy consumption. Furthermore, difficult plant control can lead to compromised occupant comfort and shortened plant life."

1.5 SOLUTIONS/SUGGESTIONS

- Challenge "rules of thumb" and/or brief requirements which may be out of date. For example, obtain current equipment load data that matches the intended use.
- Conduct an accurate load estimate, using AIRAH design data, specific to project location, and then resist the temptation to apply "safety factors". Do not use W/m² or other approximate methods.
- Use a load estimation program that accounts for thermal storage and diversification of peak loads for each zone and air handling system.
- Select chiller sizes and staged or variable speed pumps and fans to ensure good part load performance. Most buildings spend the bulk of their operating hours running at less than 50% load. Individual chillers usually become less efficient once the load falls below 50%. This problem is exacerbated if the chiller is oversized.
- Allow for unknown future tenancies by designing flexibility into the system, not by over-sizing. For example, generous sizing of distribution pipework and ductwork will allow available capacity to be redistributed.
- Provide an auxiliary tenant condenser water loop to handle high load areas.
- Consider using an Integrated Design Process, build an integrated load and energy use simulation model and test different operational scenarios
- Consider commissioning/maintenance aspects for the system
- Use comprehensive Life Cycle Cost analysis for selection of the most optimal design solutions.
- Mandatory disclosure regulations due to be introduced by the end of 2007 for energy performance of buildings upon sale or leasing will place pressure on design teams to achieve better performance – right-sizing will be part of the solution.

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PERFORMANCE BASED BUILDING

Refereed Paper

QUALITY PERSPECTIVE OF CONTRACTOR PERFORMANCE APPRAISAL

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ABSTRACT

The Hong Kong Housing Authority (HKHA), the largest developer of public housing in Hong Kong, has used a performance appraisal system known as Performance Assessment Scoring System (PASS) for measuring contractor performance for more than 15 years. Assessment is made by the relevant project team members within the HKHA's organisation (the Second-Party Assessment instead of the third party assessment) and is not supported in the quality management system.

The PASS score is mainly used for summative purposes for ranking the tendering opportunities for the contractors. This summative performance appraisal tends to prevent change and improvement in the system and is contra to the fundamental philosophy of quality management i.e. the concept of continuous improvement. This paper covers a detailed survey and review of the literature dealing with the application of the theoretical framework underlying quality management and quality assurance PASS system. It illustrates the findings of a survey (conducted in 1999) of a group of construction managers regarding their perception on third party assessment, and formative or summative use of PASS. The findings are statistically analysed and reveal that the respondents tend to support the third party assessment and have a higher preference for the assessment team to be comprised of members from independent consultant firms. Further interpretation of the findings is also made with reference to the organisation's culture in Hong Kong.

Keywords: performance assessment, third-party assessment, quality management

1.0 PERFORMANCE MEASURE FOR CONTRACTORS

During the last ten years, there has been an increasing awareness of the needs of improved performance and quality within the total building process, which has hastened the evolution and subsequent adoption of quality assurance in building works. Quality assurance is defined as a systematic way of ensuring that organised activities happen in the way they are planned. It is a management discipline concerned with anticipating problems and creating the attributes and controls which prevent problems arising (CIRIA, 1985). The philosophy of performance improvement in total quality management has recognised that measurement in the design, procurement, and construction process is important (Glagola, Ledbetter, & Stevens, 1992). The construction industry appears to be lacking a clear and uniform evaluation standard for overall construction quality when compared to other industries e.g. the manufacturing industry (Low, 1993). The quality of construction projects has generally been evaluated by the use of subjective measures (Low, 1993). To overcome this difficulty, various objective techniques for measuring contractor performance have been developed.

Concurrent with the increase in quality awareness in construction, the Hong Kong Housing Authority (HKHA) has initiated a unique assessment scheme for measuring contractors' performance in Hong Kong. This assessment scheme is known as the Performance Assessment Scoring System (PASS). Performance is defined in terms of individual-level production quantities and measured by self-reports, supervisor's ratings, or output counts, although some studies have employed group or organisation-level reports, ratings, or counts (Wagner III, 1994). The PASS is adopted to evaluate the performance of public housing contractors regularly used on on-going jobs. Assessment is made on a regular and prearranged basis and is conducted according to a documented format as laid down in the PASS Manual and Supplement. The assessors come from the HKHA's in house project team, with the assistance of the contractor's site staff (HKHA, 1996) and are required to follow the PASS Manual and Supplement systematically. Bates, (1992) emphasized that PASS could provide an objective measurement of quality and it is possible to compare contractor with contractor, site with site, and to explain where non-compliances are occurring and whether there has been improvement over time. Objective measures are based on independently-observable facts (Schalkwyk, 1998) and have the advantage of not being biased by whoever is providing the opinion or the estimate (White, 1996). There was a noticeable drive towards standardisation and objectivity in assessment procedures for the appraisal of performance (Gill,1977 & Long, 1986).

2.0 CRITICAL REVIEW OF PASS

The PASS assessment scheme can be classified as Second Party Assessment which involves developing a quality system and inviting the client (the HKHA), to collaborate in its development in order to fulfill the requirements for quality as specified by the client (the HKHA) (Griffith, 1990). This type of assessment method seems at odds with the concept of quality assurance which emphasized shifting from internally and organically generated concern with quality, by the actual producers, to a mechanically imposed set of procedures whose efficacy is guaranteed by external controllers and assessors (Seymour et al., 1990). This notion corresponds with the evolution of Third-Party Assessment, which is normally undertaken by an independent body and has no contractual relationship with the contracting firm. Its purpose is to provide confidence that the services supplied will comply with the specified requirements (Chan, 1996). Without the involvement from "outside industry" professional bodies, the objectivity of Second Party Assessments for PASS may be impaired by the idiosyncratic biases of a particular assessor e.g. the assessor may have already built up a relationship with the contractor from a previous project as a project team member. Accordingly, it is not uncommon for the project staff in the Hong Kong Housing Department to be rotated regularly from one section to the other. The concept of PASS, by its reliance on the second party assessment method rather than the third party, appears to be lacking. It will be interesting to address the question: "Could the Third-Party Assessment method be used to minimise the effect of the idiosyncratic biases?" If true, this will minimise the possibility of subjectivity in assessing contractor's performance.

The PASS score is mainly used for ranking the tendering opportunities for the Contractors. This performance measure is used to identify substandard work that requires remediation and to evaluate the contractors' performance for both "punish and reward" purposes. This performance appraisal process is detection oriented rather than prevention oriented. Some total quality management advocates see it as a flaw and require it to be eliminated (Milliman, et al. 1997).

Whether or not the PASS should be used for judgmental purpose e.g. rewarding the good performers with more tendering opportunities and for penalizing the poor performers, is a controversial issue. While the Housing Department believes that this approach will motivate contractors to improve their performance, some researchers criticized that granting higher tendering opportunity to contractors bearing higher PASS scores is not adequate to stimulate a quality drive (Chan et al., 2003). Many authors, (McLagan and Nel, 1996) believe that performance measures should not be used as weapons to punish or blame contractors. Individuals blamed for mistakes are unlikely to search for and correct them and thus key system failures will not be addressed. Deming and a number of other theorists advocate eliminating performance appraisals (Milliman et al., 1997). Deming views performance ratings as a lottery because raters are unable or unwilling to distinguish between person-caused versus system-caused sources of variation. This results in lowering morale and creates other dysfunctional results (Cardy and Dobbins 1994). Further, appraisals encourage appraisees to perform well within the current system, but prevent change and improvement in the system (Bounds and Pace, 1991 & Cardy and Dobbins, 1994). This seems to contradict the achievement of continuous improvement, the basic philosophy tenet of quality management. McNair et al. (1990) support the use of performance measures to coach, i.e. for providing information that help people and teams improve (formative purpose), as opposed to keeping score (summative purpose).

3.0 OBJECTIVE OF THE STUDY

The above analysis reveals that PASS still has room for improvement. This study attempted to verify whether the following two aspects would be the real deficiency of PASS.

1. It uses the second party assessment method instead of the third party assessment method.
2. It uses appraisal results for summative rather than formative purposes.

The partial implementation of quality assurance system slows the process towards project-wide quality management (Abdul-Rahman, 1996). The outcome of this study would serve as the feedback information for the review of the PASS process and enhance the effectiveness of the quality assurance system.

4.0 RESEARCH METHODOLOGY

The methodology for this research is a formative evaluation research approach which focuses on diagnosing two of the areas of weaknesses in the PASS system and making recommendations for improvement based on the analysis of the survey results. The major target of the respondents in the survey is the middle managers in the contractor organizations because they are the operational personnel who encounter the implementation of the PASS system. The questionnaire was divided into 2 parts:

Part 1: Perception of Respondents
This part is divided into two Sections, A & B with the aim to explore the perception of middle managerial staff in the contractor organization on two major aspects:

Section A - the adoption of third party assessment in the PASS system with a view to increasing its objectivity and effectiveness for measuring contractors' performance, and to suggest any change to be made on the operational details of the PASS system. Four questions were set to seek answers for the following research question:

Which types of assessment method will be accepted as a more objective assessment of the PASS appraisal?

Section B - the determination of whether the PASS assessment should only be used for ranking tendering opportunities (i.e. the summative use) or as a guideline to formulate an improvement plan for performance improvement (i.e. the formative use). Three questions were set on this aspect to find out the answer for the following research question:

Do the contractors agree that the use of PASS scores for summative purposes could motivate the contractors to improving their performance?

Each question was provided with 5 ranges of different answer categories in a Likert-type scale with scores ranging from 5-1indicating the strength of agreement or disagreement. The Likert-type scale is a form of closed questions, which are constructed to force respondents to choose between a limited range of possible answer, thus giving a more discriminating answer. Each answer is ascribed an appropriate code (for example, respondents who answer 'agree' to a Likert-style statement will receive a code of 4 for that question). 'Coding' means the assignment of numbers to each answer category so that common answers can be aggregated (Bryman, 1989).

As quality is a multi-faceted concept (Low, 1993) and the above review is derived from the quality management/assurance theory, the authors have an interest to examine whether the respondents' perceptions would be affected by whether or not they had any training in quality management/assurance. In this regard, one question was set to ask respondents on this issue. The findings would be used to test the following null hypothesis.

Ho: there is no difference in responding to the variables in Part 1 of the questionnaire for respondents with or without prior training in quality management/assurance.

The questionnaire was sent to middle management staff, such as construction managers, site managers or site agents employed in the HKHA list of new building works contractors. The records obtained from the HKHA on 10th November 1998, indicated that the total number of Housing Authority's listed Building Contractors for New Works including both NW1 & NW2 is 50 (HKHA, 1998). Based on the assumption that 5 managerial professionals are employed in the listed building contractors, the sample size to be surveyed in the studies would be around 250.

5.0 DATA ANALYSIS

As the study aims to investigate the effectiveness on PASS based on the contractors' point of view, the target group of respondents will be the project managers or others in comparable positions employed in the Hong Kong Housing Authority List of Building Contractors for New Works, (NW1 & NW2). With the assistance of the Hong Kong Construction Association for the dispatch of questionnaires to their members or non-members of the HKHA's building contractors, a total of 50 completed questionnaires was returned for analysis, giving a return rate of 20%. Although the 20% response rates was considered rather low, the Construction Association pointed out that during last two years about 70% of the HKHA's works was engaged by only 4 major contractors in the approved lists. In this regard, this questionnaire would be more easily to draw echo from the respondents of these 4 major contractors. Amongst the 50 returned questionnaires, there were 35 from these 4 major contractors. Therefore, the responses are considered to be representative of the market.

The collected data was statistically analysed. In the analysis, the level of each variable is described by its mean and standard deviation. For the analysis of the variables on the types of assessment and formative or summative use of PASS scores, a one sample t-test was performed to determine whether the mean rating of the sample was significantly different from the population mean, i.e. 3 on the five points scale. In order to determine whether the training background of the respondents would provide different results of the survey findings on the variables, a two sample t-test was performed. Under the t-test, a p-value was computed to examine the probability that the difference between the sample means was unlikely to be a coincidence. Based on the Prism summary (Motulsky, 1999), when the computed p-value is greater than 0.05, we can assume that it would not be statistical significant or the vice versa. The analytical results for each variable are summarised in Table 1 below.

Variable	Sample Mean (x)	Sample Standard Deviation (SD)	t - test	2-tailed p – value	Statistically Significant (Yes/No)
Level of Assessment					
1. Assessment by HKHA in house staff could provide a fair and objective assessment.	2.86	1.13	0.8761	0.3853	No
2. Increase objectivity by third assessment, outside the HKHA organisation	3.54	0.89	4.2903	< 0.0001	Yes
3. Assessment panel to be made up from outside consultant firms.	3.42	0.95	3.1262	0.0030	Yes
4. Assessment panel to be comprised with members selected from professional bodies and academic institutions.	3.40	0.76	3.7216	0.0005	Yes
Formative or Summative Use of PASS Score					
5. Use of PASS score for ranking tendering opportunity truly motivate contractor for performance improvement.	3.46	0.89	3.6547	0.0006	Yes
6. Use of PASS score as a guideline to formulate improvement plan.	3.31	1.10	1.9928	0.0519	No
7. Summative use of PASS score creates a facile compliance, not a genuine participation.	3.39	1.00	2.7577	0.0082	Yes

Table 1 One sample t-test on significance of variables of returned questionnaire (Sample size is 50)

5.1 VARIABLES CONCERNING THE TYPE OF ASSESSMENT

Apart from variable 1 for second party assessment, the t-test indicates that the actual scores for variables 2, 3 & 4 concerning the methods of third party assessment are significantly different from a no-change score of 3. As the p-values for both variable 3 & 4 are significant (as the p-value is very close to 0), it can be reasonably concluded that variable 3 is more supported by the respondents when comparing the mean value of both variable 3 & 4 (the mean value for variable 3 is higher than 4). This analysis therefore lends supports to the above literature review on quality management that the respondents tend to accept third party assessment and they tend to have a higher preference for the assessment team to be comprised of members from outside consultant firms. This phenomenon may result from the generally held common view that professionals in the industry will be more familiar with construction practice and procedures.

5.2 VARIABLES CONCERNING THE FORMATIVE OR SUMMATIVE USE OF PASS SCORES

As the p-values for both variables 5 & 7 are very significant, it can reasonably be concluded that the respondents have a majority view (more than 50%) to support the summative use of the PASS score for ranking tendering opportunities in order to motivate contractors to improve their performance (as the mean value for variable 5 is higher than that for variable 7).

5.3 INFLUENCE OF RESPONDENTS' TRAINING BACKGROUND ON SURVEY FINDINGS

The training background of the respondents was analysed to explore any significant difference on the survey findings of the above variables. Findings from two groups of respondents (i.e. T1 for respondents without training background related to quality management/assurance while the other, T2 for those with such training) was analysed by the two sample t-test and the t-values and p-values are summarized as shown in Table 2 below. For group T1, the sample size was 11 while T2 was 39. As the p-values for all variables are greater than 0.05, the null hypothesis Ho cannot be rejected and the difference is not statistically significant.

Variable	No Training (T1)		With Training (T2)		Two sample t-statistic	2-tailed p - value	Statistically Significant (Yes/No)
	Sample Mean (x)	Sample Standard Deviation (SD)	Sample Mean (x)	Sample Standard Deviation (SD)			
Level of Assessment							
1. Assessment by HKHA in house staff could provide a fair and objective assessment.	1.82	0.75	2.03	0.84	0.7483	0.4579	No
2. Increase objectivity by third assessment, outside the HKHA organisation	2.18	0.87	2.46	0.64	1.1814	0.2433	No
3. Assessment panel to be made up from independent consultant firms.	2.09	0.94	2.38	0.78	1.0411	0.3030	No
4. Assessment panel to be comprised with members selected from professional bodies and academic institutions.	2.09	0.70	2.41	0.64	1.4355	0.1576	No
Formative or Summative Use of PASS Score							
5. Use of PASS score for ranking tendering opportunity truly motivate contractor for performance improvement.	2.27	0.79	2.44	0.72	0.6774	0.5014	No
6. Use of PASS score as a guideline to formulate improvement plan.	2.27	0.79	2.23	0.84	0.1408	0.8886	No
7. Summative use of PASS score creates a facile compliance, not a genuine participation.	2.55	0.69	2.13	0.77	1.6276	0.1103	No

Table 2 Two sample t-test on significance of variables of returned questionnaire.

6.0 CULTURAL PERSPECTIVE ON SURVEY FINDINGS

Although a lot of articles commented that performance appraisal should not be used for summative purpose, the analytical results as stated above indicate that the respondents generally accepted the summative use of the PASS score for ranking tendering opportunities in order to motivate contractors to improve their performance. As organizational culture appears to be gaining support as a predictive and explanatory construct in organization science (Liu, 1999), the authors have attempted to interpret the findings concerning these variables from the cultural perspective.

According to the study by Hofstede, (1984, 1991), Hong Kong with a Chinese population base is shown to be a large power distance and low uncertainty avoidance society. Large power distance indicates a need for dependence on more powerful persons. In the large power distance situations the inequality between superiors and subordinates is high and organizations tend to centralize power in a few hands and subordinates are expected to be told what to do (Mathews et al., 2001). In the countries with low uncertainty avoidance e.g. in Hong Kong, there is less need of a formal system (Hofstede, 1994). Following the increase in quality awareness in the Hong Kong construction industry and the launch of the Preferential Tender Award System for building contracts in 1999 from HKHA (HKHA, 2002), the contractors as business partners with the HKHA are encouraged to realize the necessity to have a fair and objective system to differentiate good performance. In this respect, the HKHA is vested with the supervisory power to monitor contractor performance in a building project and the contractors would then take the PASS exercise to calculate their performance as recognition of their achievement.

The construction industry's workforce is predominantly male in most countries (Ang and Ofori, 2001). This 'macho' culture reinforces the masculinity characteristics in the more masculine society as characterized in Hofstede, 1994. In a more masculine society, humanization takes the form of masculinization, allowing individual performance (Hofstede, 1980). Achievement motive has become popular in societies like Hong Kong with the combination of weak Uncertainty Avoidance and relatively high Masculinity (Hofstede, 1980). This leads to a conclusion that the concept of the achievement motive presupposes two cultural choices, i.e. a willingness to accept risk (equivalent to weak Uncertainty Avoidance) and a concern with performance (equivalent to strong Masculinity) (Hofstede, 1980). This characteristic seems to reflect that the PASS has become an achievement motive to drive the contractors to achieve quality improvement. Table 3 illustrates the list of relevant cultural dimensions and their characteristics in the workplace inherent to Hong Kong people which may explain why PASS is adopted as the achievement motive for improving contractor performance.

Cultural Dimensions	Level Inherent To Hong Kong Workplace	Relevant Characteristics To Explain Why PASS Could Be An Achievement Motive
Power Distance	High	Inequalities among superiors and subordinates; Hierarchy in organizations; Centralization in making decision by superiors; Subordinates expect to be told what to do.
Uncertainty Avoidance	Low	Comfortable in ambiguous situations and with unfamiliar risks; No more rule unless strictly necessary; Hard-working only when needed; Motivation by achievement and esteem or belongingness.
Masculinity	Medium to High	Performance society ideal; Stress on equity, competition among colleagues, and performance; Society values are material success and progress.

Table 3 List of selected cultural dimensions and their characteristics to explain why PASS Could Be an Achievement Motive (Extracted from Hofstede, 1994).

7.0 RECOMMENDATION AND CONCLUSION

Although quality management practitioners have raised a number of objections to the performance appraisal process, performance appraisal has been used by many organisations for legal reasons to justify termination, promotion and other administrative decisions (Milliman, et al., 1997). This is similar to the application of PASS for ranking contractor tendering opportunity. The appraisal process should be substantially revised or improved so as to minimise any shortcomings which may occur in the appraisal process (Milliman, et al., 1997). The survey findings drew up the following recommendations for improving the PASS process from the following two areas:

1. Upgrading the appraisal process to 3rd party level, from the current of 2nd party level drawn from HKHA in-house staff.

   The analytical results as stated in Section 5.1 above reflect that the third party assessment appears to be more favourable to the contractors. This finding corresponds to the community's legitimate expectation for the Hong Kong Housing Authority to adopt an objective third party scrutiny of her housing projects (HKHA 2000). In response to the increasing aspirations for better quality, the Authority has introduced two new practices a few years ago.

   (a) An Independent Checking unit (ICU) was established towards the end of 2000 and is now working towards a comprehensive third party regulatory control system independent of the Housing Department's business divisions (HKHA, 2002). The Independent Checking unit (ICU) is operated with building control mechanisms based on those of the Hong Kong Buildings Department and scrutinizes and approves building proposals from Housing

Authority (HA) developments. This unit can be regarded as an external Housing Department because many of its member are remunerated from the Buildings Department's funds.

(b) Since implementing the Performance Assessment Scoring Scheme (PASS) 15 years ago, the Housing Authority has realized the importance of objective and independent assessment of contractor's performance. The PASS assessment has been revised to include more independent teams to carry out more works output assessments, as well as the final assessment (HKHA, 2002). The independent teams comprise of assessors selected from members outside of the original project team members. This practice is also considered as Second Party Assessment since assessors are the employees of the client's organization, the Housing Department, albeit they are independent of the original project team members.

The survey finding also suggested that the third party assessment team should be made up from outside consulting architects or surveyors who do not have direct relationships with the client, i.e. the HKHA or the contractor side. The current practice as stated in (b) above seems to have room for further improvement to enhance the objectivity of the assessment process in accordance with the principles of quality management and assurance. In this regard, this survey's results could become a blueprint for developing an improvement plan to include the appointment of outside consultants as third party assessors to conduct the PASS assessment. This plan should have a planned and independent evaluation system to help determine the contractor's level of achievement against the defined standards as stated in the PASS Manual and its Supplement. In order to ensure that external consultants follow procedures, comply with the appropriate documentation and provide timely, fair and accurate assessment, substantial training should be introduced to enable those consultants to become more familiar with the working and operation of the PASS process and the assessment procedure.

2. Maintain the existing summative use of PASS score for ranking tendering opportunities for contractors.

   The analytical results as stated in Section 5.2 above reflect that the respondents generally accept the PASS score as a motivation for performance improvement. In high masculinity cultures, achievement is defined more in terms of recognition and wealth (Hofstede, 1984). The use of PASS scores for ranking tendering opportunities for contractors and the introduction of the Preferential Tender Award System in 1999 to secure contracts for those contractor who consistently achieve outstanding performance, already seem to serve this purpose.

   Carroll and Schneir (1982) define performance appraisal as the process of identifying, observing, measuring, and developing performance in organizations. Formative use should therefore also be adopted in parallel to the summative use in the PASS appraisal process so as to provide a betterment of incorporating one of the key elements, 'developing' in the performance appraisal process for achieving the key concept for continuous improvement, the basic philosophy tenet of quality management.

If the above two recommendations are incorporated into the future review of the PASS process, it could provide new insights into how the principles of quality management could be applied in the PASS process. Similarly, this could facilitate the use of the PASS score as feedback information for continuously improving the contractor's performance and result in PASS becoming more objective and effective as it gains trust and respect from the participating parties.

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FACILITIES MANAGEMENT

Refereed Paper

FACILITY MANAGEMENT AS THE CATALYST TO ACCELERATE THE EVOLUTIONARY CHANGES IN WORKPLACE ARCHITECTURE

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ABSTRACT

Technology has fostered many alternative ways of working which have changed the way we work and the way we use the built environment. Whilst most of these alternative ways of working offer tangible benefits to companies that have properly adopted them, poor implementation has caused losses that have slowed down the process of adoption. This paper recognises the benefits of adopting alternative ways of working, but also warns about the fragility of working environments. A well planned adoption process is required in order to ensure implementation success. Based on strategic asset management together with Rogers' diffusion of innovation theory, a method is proposed to accelerate the adoption process of alternative ways of working whilst keeping the balance between people, space and technology.

Keywords: office design, alternative ways of working, diffusion of innovation

1.0 INTRODUCTION

"*In Australia the increasing use of technology is dramatically changing the way people live and work*"
(Martino 2001)

Technology is transforming almost everything we do in a fashion that is modifying our society by changing our value systems, power structures, everyday routines and environment (Linturi 2000). Advances in technology are having a major impact on shaping the office environment and the way we work (Stallworth and Kleiner 1996; Robertson 2000).

The traditional definition of an office as the place where people read, think, write, and communicate; where proposals are considered and plans are made; where money is collected and spent; where business and other organisations are managed is shifting as technology is changing the way we perform such activities (Giuliano 1985). Further, office work is no longer confined to an office environment, mobile technology allows people to work as effectively from home, airports or cafes (Stocks 1998). As a consequence, workplace architecture needs to evolve.

These rapid and drastic changes in technology are creating an imbalance in the '*organisational ecology'* which poses a challenge to office workers, business managers, facility managers and architects. Becker and Steel (1994) describe organisational ecology as the way *"organisation leaders choose to arrange their employees in space and time in pursuit of a long-term competitive edge"*. The three key elements of organisational ecology are: 1) the physical settings in which work is carried out, 2) the processes used for planning and designing the workplace system, and 3) the way space, equipment, and furnishings are allocated and used over time. These three elements are affected by the nature of the work and business processes, the organisational culture and corporate values, cost of space, operational health and safety requirements and workforce demographics. A change in any of them is likely to alter such ecology. It is this holist approach that differentiates organisational ecology from traditional organisational behaviour disciplines.

Some changes in office buildings are more evident than others. For example, whilst in 1892 the Masonic Temple in Chicago reached 20 storeys, today Taipei 101 building is 509m tall (Reuters 2003). However, office buildings are not just taller. More importantly and often overlooked, is the fact that their organisational ecology has evolved as a consequence of the technology adopted in the workplace.

Giuliano (1985) states that "*new technology inevitably affects the organisation of work*" and identifies three stages of office organisation characterised not only by technology but also by style of management, personal policies, hierarchy of supervisory and managerial staff, standards of performance and human relations amongst the people involved in the office and their clients. According to Giuliano there are three different office organisations:

1) The pre-industrial office: depends on the performance of the individuals, without much benefit from machines. There is little systematic organisation. Each person works independently, physically moving around to retrieve a file. Individuals have different styles of work and human relations and values are important. However, the only way to overcome an increase on the work load is by hiring more employees.

2) The industrial office: is a response to the limitations of its predecessor and introduces the principles of work simplification, specialisation, and time-and-motion efficiency. It is essentially a production line, where even personal interaction is standardised. Work moves from desk to desk as parts move along an assembly line, making jobs simple, repetitive and unsatisfying. The fragmentation of responsibility created bureaucracy and proliferation of paperwork. Workers may not know the overall task

to which they are contributing. Everyone has to work together during the same hours in the same office to sustain the flow of paper.

3) The information age office: combines systems and machines to the benefit of workers and clients, but tries to maintain the values of the pre-industrial office. It exploits new technology, yet it returns to people-centred work rather than machine-centred work. The machine is paced to the needs and abilities of the person who works with it. Instead of executing a small number of steps repetitively for a large number of accounts, one individual handles all customer-related records. Staff reduction of as much as 50% is common. Information is updated as it becomes available, and there is no uncertainties related to the '*work in process*'. Productivity is not longer measured by hours of work or number of items processed, but by customer satisfaction.

It is unclear what will follow Giuliano's information age office, but Marmot and Eley (2000) go further by questioning the need for office buildings in the future. They argue that while technology once acted as a '*glue'* forcing people to be in a specific place in order to share equipment – e.g. typewriters, adding machines, etc. – and interact with their workmates, today's technology is acting as a '*solvent*' which eliminates such need and allows people to use mobile technology and interact from different places. Moreover, they maintain that whilst offices flowered as a building form and a social structure for a short, yet intense period, this could be a short-lived phenomenon, a transitional stage in economic revolution. Hence, it is uncertain what type of office building, if any, will be required in the future.

2.0 ALTERNATIVE WAYS OF WORKING

Since 1964, when IBM introduced a magnetic-card recording device into a Selectric typewriter, the future of the office and our expectations of it, changed forever. The feeling of technology domination felt after the post-industrial innovations (1960's–1970's) made us believe that offices in the future, that is today, would be run by robots whilst workers would enjoy free time (Dowdy 2000). This belief was so strong that social scientists worried about the vast amount of leisure time the workforce would have, and ignited fears of a jobless society (Castells 1996). Nevertheless, in Japan there were 160 official cases of '*karoshi*', death from overwork in 2002, and 43 more people committed suicide because of overwork. The French government is assessing lengthening its 1998 workweek arrangement (Tischler 2005). Even Spain's proud '*siesta'* tradition is threatened by today's working habits (Pogash, McLean et al. 2005). In Australia, the number of employees who work overtime on a regular basis increased to nearly 3 million in 2003 (ABS, 2005).

Although not in the expected time frame, and certainly not in the fashion of a "*paperless, push-button, electronic world where high finance meets high technology in a triumph of white collar productivity"* (Immel 1985), alternative ways of working are changing the way we work and the way we understand work (Austin, L.Bain et al. 2001).

Alternative workplaces emerged as a response to traditional offices. On the one hand, traditional offices are designed in accord with long-held and unspoken beliefs about the nature of work in order to support production rather than innovation. Traditional office arrangements are centralised, focus on status, and assume that employees will be in their assigned location during fixed hours. On the other hand, alternative workplaces have fewer preconceived notions about what constitutes correct workplace design, yet tend to include a variety of central and dispersed work locations. They balance production and innovation work, include work flexibility about when and where work is done and minimise design attributes that explicitly display status (Austin, L.Bain et al. 2001). Questions like: *"do certain people need to come to the office? Does the office need to take a certain form? Can we do* *things differently and more efficiently?"* are redefining the way we work by offering a new array of flexible working options (Stocks 1998).

There are numerous models of alternative ways of working such as teleworking, hot-desking, virtual office, hoteling, moteling, caves, commons, cottaging, guesting, just-in-time office, touchdown carrels, and so on (Stocks 1998; Marmot and Eley 2000; Austin, L.Bain et al. 2001). Whilst a full explanation of each of these options is beyond the scope of this paper, they share common traits like increased flexibility in workplace and working time as well as a more efficient use of space. Alternative ways of working not only represent benefits to individuals, companies and cities, but they also reflect benefits to the environment (ITAC 2004; SUSTEL 2004).

Companies that implement flexible working can reduce, or even eliminate, the need for buildings at all. In a study done by SUSTEL (2004), 12 out of 30 companies needed less office space as a result of teleworking, and an additional three were expecting such benefit in the near future. A UK company closed its central office. Alternative ways of working can also help to reduce the need for commuting – including the environmental impact that derives from it (Nilles 1998).

Unfortunately, *"in practice it is economics rather than environment which is the main driver"* (SUSTEL 2004). Still, a study done by Actium Consult and Cass Business School (2005) in the UK proves that from a financial point of view alternative ways of working make sense, since rent represents nearly 50% of total office cost. Therefore, considerable savings can be achieved if the amount of space required by each employee can be used in a more efficient fashion, reduced or simply eliminated. The same study argued that through alternative working a medium size business – 500 staff – can make a saving of £0.77m per annum on property costs. However, it is important to notice that flexible working alters the traditional ratio of 65% property costs and 35% IT costs, to 55% property and 44% IT. The remaining 1% is the cost of change in management required to balance the organisational ecology.

3.0 ADOPTION OF ALTERNATIVE WAYS OF WORKING

Poor implementation of alternative ways of working has resulted in costly mistakes with an impact on adopters' trust which have slowed down the adoption process. One of the most representative and well-known cases is the endeavour undertaken by Jay Chiat, who transformed a multimillion dollar advertising agency into "*the laughingstock of the industry"* whilst trying to '*go virtual*' (Tsuchiya and Vithayathawornwong 2005). After a painful implementation processes, Chiat's virtual office project was declared officially dead and people moved back to the paper-factory, hardwired-phone and a-desk-per-person office (Marmot and Eley 2000).

Whilst the specific causes of failure in the Chiat Day case were poorly planned integration, intransigent policies, not enough resources and lack of personal space (Berger 1999; Tsuchiya and Vithayathawornwong 2005), the implementation of alternative ways of working across the board is full of challenges.

3.1 PARADIGM CHANGE

The first of these challenges is the inertia of old paradigms fuelled by our inherit resistance to change. In 1872 Walter Bagehot wrote "*one of the greatest pains to human nature is the pain of a new idea. It… makes you think that after all, your favourite notions may be wrong, your firmest beliefs ill-founded… Naturally, therefore, common men hate a new idea, and are disposed more or less to ill-treat the original man who brings it*" (Bagehot 1999).

3.2 CULTURAL CHANGE

Another hurdle to overcome is the strong cultural role that the old-fashioned office building still plays. Giuliano (1985) describes the attributes of a physical office as home for organisations, a place to meet face to face, and a work-oriented environment away from home.

Parallel to this, are the negative side effects of alternative ways of working. For example, hot-desking takes away the sense of belonging, which is a very secure symbol for people and teleworking jeopardizes the cherished boundaries between home and office (Dowdy 2000; Marmot and Eley 2000; Lake 2005).

3.3 CHANGES IN POWER AND COMMUNICATION AMONGST DISCIPLINES

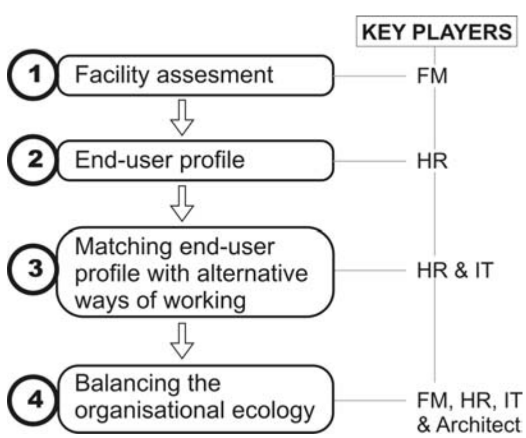
A successful adoption of alternative ways of working requires effort from a variety of disciplines including Human Resources (HR), Information Technology (IT) and Facility Management (FM).

However, as noted by Robertson (2000) these groups rarely interact with each other and are mainly concerned about their own area of responsibility. The HR group is seen as the group that focuses on initiatives that are good for the employees, but without clearly adding real business value. The FM group is regarded as only interested in cutting real estate costs by relying on old paradigms – e.g. reduce the size of workstations – and rarely do they offer leading-edge solutions to space challenges. Finally, the IT group seems to deliver technology for the sake of technology, without fully taking into consideration people or management issues.

4. A PROPOSED MODEL TO ACCELERATE ALTERNATIVE WAYS OF WORKING

Due to the fragility of the organisational ecology and the challenges inherent in adopting alternative ways of working, a method is proposed to facilitate the implementation process within individual companies and accelerate the process of adoption on a global scale. To achieve this, the proposed method relies on timely adoption and tailored solutions based on FM principles as well as Rogers' diffusion of innovation theory. Figure 1 summarises the steps and identifies the key players on each of them.

Figure 1: Model to accelerate adoption of alternative ways of working.



Step 1: Facility assessment

The first step is to identify when the facility is due for capital renewal. Capital renewal differs from maintenance and repair in that the former is a comprehensive action to completely replace an existing asset – even to the extent of changing its functionality or location – whereas maintenance and repair are interventions just to ensure an asset reaches its optimal service life (CICA 1989; Vanier 2001).

Matching the time when a facility requires capital renewal with the adoption of an alternative way of working will provide the flexibility required to redesign the space and functionality to host the new working environment. Therefore, the facility manager plays a crucial role in this step as he/she is the responsible for managing the substantial maintenance, repair and renewal work and is in a constant technical challenge to weight the cost of these decisions versus the technical and functional benefits of implementing a solution (Vanier 2001).

Gordon and Shore (1998) identify three planing horizons for asset management based on their projection into the future:

a) Operational planning: within the two-year time frame;
b) Tactical planing: within the two to five years time horizon; and
c) Strategic planning: planning beyond the five-year term.

Because most building components or systems have service lives ranging from 5 to 35 years (HAMP 1995; Vanier 2001) it is in the strategic asset planning horizon that capital renewal is planned. However, because not enough is spent on maintenance and repair, owners are accumulating an ever-increasing maintenance deficit, which leads to premature failures and premature renewals (Vanier 2001).

The capital renewal cost in the USA is approximately US$370.00 billion. Although this figure includes all type of infrastructure, not only office buildings, it denotes the magnitude of the challenge. Proportionally, similar scenarios are shared by Canada and Australia (Vanier 2001). It is estimated that the infrastructure renewal liabilities for Victoria, Australia, are in the order of AUD$23 billion (Burns, Hope et al. 1999).

Step 2: End-user profile

Once the facility is due for capital renewal, the end-user profile of such facility can be matched to one of the five types of adopters depending on their readiness and capability to adopt an innovation as per Rogers' diffusion of innovation theory.

Rogers' diffusion of innovation theory describe the process by which an innovation, in this case alternative ways of working, is communicated through certain channels over a period of time amongst the members of a social system. Such process starts with the awareness stage, followed by the interest stage, the evaluation stage and trial stage to culminate in the adoption stage. Through the awareness stage to the trial stage the individual has the option to reject the innovation. Once adopted, the innovation can be discontinued by disenchantment or by replacement (Rogers 1995).

Rogers classifies the unit of adoption, in this case the end users, into:

1) Innovators: The risk takers. They have the ability to understand and apply complex technical knowledge and to cope with high degree of uncertainty about the innovation. But most of all, they control substantial financial resources to absorb possible loss from an unprofitable innovation.
2) Early adopters: They are successful and respected by peers. Their high degree of opinion leadership affects most systems and they serve as role model for other members or society. They play a key role in the adoption process determining the time and extent in which an innovation will be adopted.

3) Early majority: Whilst they do not take as much risk as their predecessors, they do accept an innovation before the average person. They interact frequently with peers, yet seldom do they hold positions of opinion leadership. They deliberate before adopting a new idea.
4) Late Majority: Their education and income are limited. Being sceptical and cautious, they will usually adopt the innovation under economic or peer pressure.
5) Laggards: They posses no opinion leadership, are isolated or surrounded by other laggards. Their resources are limited. Their point of reference is the past, therefore are suspicious of innovations and frequently by the time they adopt an innovation there is a new one already starting to take its place.

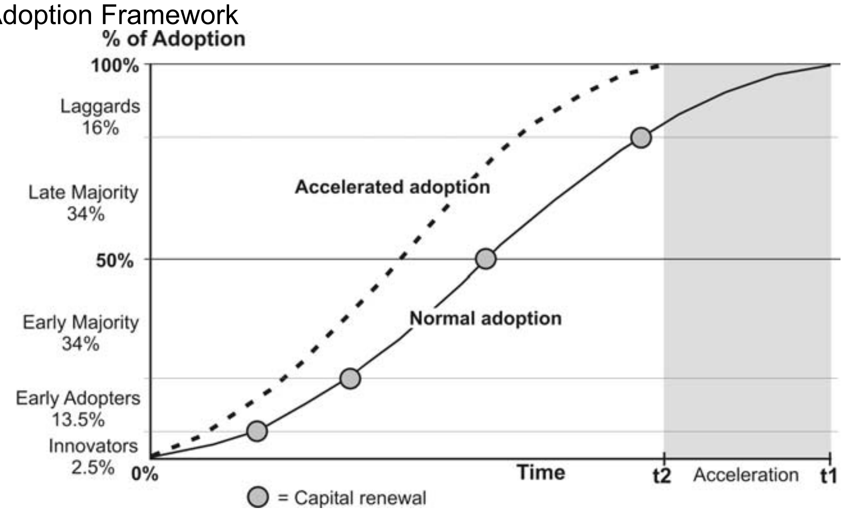
Step 3: Matching end-user profile with alternative ways of working
The process of selecting an alternative way of working is complex. It depends on the type and size of business, management style, structure and philosophy of work amongst other variables. However, this method argues the type of alternative way of working and the fashion in which it is implemented depend on the type of the end-user as described in step 2.

For example, two similar companies in type, size, structure, etc, but one being an '*early adopter*' and the other a '*late majority*' will differ in the ratio of adoption and/or in the suitable type of alternative way of working. That is, a company with an end-user profile of '*early adopter*' will be better-off with an adoption rate of 60% traditional – 40% alternative, whereas a '*late majority*' end-user type company will benefit from a rate of 80% traditional and 20% alternative.

Step 4: Balancing the organisational ecology
Finally, a joint effort from FM, HR and IT, together with the architect is required in order to design the new space that will host the new activities in balance with the people and technology.

The timed and tailored adoptions of alternative way of working as suggested by this method are proposed to collectively accelerate the global adoption process as shown on figure 2. Figure 2 shows the typical S-shaped curve that indicates the standard adoption of alternative ways of working through time, continuous line, and the accelerated process, dotted line.

Figure 2: Adoption Framework



5.0 CONCLUSIONS

There is an evolution in workplace architecture and organisational ecology as a result of alternative ways of working fostered by technology. Technology is revolutionising the way we work, how we work and where work.

The future of the office is uncertain. The office and the workplace is in constant change and its direction will depend to a large extent on the time and manner by which alternative work practices are adopted by companies, organisations and society at large.

A planned, integrated and multi-disciplinary method of adoption of alternative ways of working is proposed to increase the success rate within individual implementations and to accelerate the process of adoption at a global scale.

Matching the implementation of alternative ways of working with the capital renewal will minimise the implementation costs. Therefore, facility managers play a crucial role as the agents that provoke the change. Parallel, Rogers' diffusion of innovation theory helps accelerate the adoption process.

By applying the proposed method, an accelerated adoption can be achieved by reaching the same population in less time ($t2 < t1$). Such acceleration will capitalise sooner all the economic and environmental benefits of alternative ways of working.

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INFORMATION AND COMMUNICATION TECHNOLOGIES IMPROVING EFFICIENCIES

Case Study

PULSE°, BUILDING INDUSTRY PERFORMANCE MEASUREMENT FOR INFORMED DECISION MAKING

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ABSTRACT

A Building industry summit in 2001 highlighted the need for leadership and industry measurement as the basis for better industry management. Integrated into the Building Commission's Corporate Plan, the pulse° website launched in 2004, is the platform for industry measurement.

The vision for the building industry in Victoria was one that created Quality Buildings, an Attractive Industry and Satisfied Consumers, which then formed the framework of pulse°. Pulse° is a world first portal of building industry intelligence, providing unique and timely data, analysis and expert commentary. Designed to enhance and develop world best practices on decision-making across the industry, pulse° provides qualitative and quantitative information on 150 measures, enables interactive use and also provides some in-depth data.

Pulse users have indicated so far that the data is highly valued, used and accepted by all areas of the industry. Anyone interested, regardless of their analytical skills, can access information on the building industry from the one central website: there is an average of 50 users per workday and this number is growing. Pulse° demonstrates the Building Commission's leadership by equipping the industry to deliver better decision-making for a better-built environment.

Keywords: Online-tool, statistics, analysis, central, building, decision-making

1.0 PULSEº INTELLIGENCE FROM EVERY ANGLE

Great visionary projects of today are no longer just about physical structures. To devise ways of improving the built environment of the twenty first century requires a delicate and unusual combination of innovative thinking, strong leadership, creative solutions and cutting edge technology. The outstanding pulse° project, initiated by the Victorian Building Commission, and launched in April 2004, is one such exemplar.

Pulse° is a sophisticated, living multi-media tool, combining the latest building statistics regulations and legislation, with expert commentary, analysis and information on Victoria's building industry, all in one central website.

Pulse°'s practical aim is to help the building industry be more competitive by making better-informed business decisions, leading to better building outcomes for the industry and the State. It is a clear example of leadership and excellence by the Victorian Building Commission, which holds the potential to expand into a national product of the future.

Website: www.buildingcommission.com.au/pulse

2.0 WHAT IS PULSE°?

The catalyst for the pulse° project came four years ago when the Victorian Building Commission held an Industry Summit with Builders, Developers, Local Government and industry bodies, to map industry outcomes. At the summit, all agreed that the ideal vision for the building industry in Victoria was one that created Quality Buildings, an Attractive Industry and Satisfied Consumers.

A decision to work together to reach and maintain such world best practice standards was another positive outcome of the Summit. The clients and stakeholders, the industry leaders, also made it clear to the Building Commission that, if the building industry was to achieve its vision, it needed the Commission to help through better leadership, and the provision of in-depth data and industry measurement. Technology and greater economic literacy in the twenty first century was changing the building industry from one where practitioners relied on anecdotal evidence when making decisions, to one where it was necessary to know and utilise the latest economic, legislative and societal statistics and surveys available.

To satisfy this demand for information, the Building Commission added to their Corporate plan a vision to provide access to comprehensive and accurate information about the industry's performance, its issues and its needs.

Pulse° is the Building Commission's cutting-edge, visionary initiative that answers this challenge. It provides support to achieve the best industry outcomes and shows a way ahead for the industry into the future. It is a sophisticated tool, based on a central and constantly updated and evolving website, augmented by regular email, and printed updates and publications.

Until pulse° was launched in April 2004, no central source of industry-wide information was available to the building sector in Victoria. Internationally as well, no one had attempted to compile a building industry project of this breadth and scope before.

The pulse° project brought together, for the first time, highly fragmented data from a variety of places, such as the Australian Bureau of Statistics, Victorian WorkCover Authority, the Reserve Bank, EcoRecycle and Building Commission unique and specific data. And where the statistics that the industry wanted did not exist, new research was conducted. With the first in 2003, there is now a three year trend line. The aim of pulse° was to present intelligence from every angle, on every aspect of the building industry, to help everyone better understand the big picture that is the building industry in Victoria today.

Pulse° is about better data, better knowledge, better analysis and better expert commentary; all leading to better decision-making and competitiveness. But it is more than just a mass of figures. Because people understand and use information in different ways, it is deliberately made up of a mix of charts and graphs, written interpretation and analysis.

The pulseº framework helps make sense of the available data, making it easier to understand what kind of information is available from a categorisation view. It details 16 elements and some 150 measures of data that contribute to the three industry outcomes; Quality Building, Attractive Industry and Satisfied consumers, as translated at the Industry summit by the Building Commission's clients. The 150 measures is aggregated into the 16 elements which cover Building control, Building standards, Consumer expectations, Consumer information, Community perceptions, Disputes, Employment profile, Environmental performance, Industry structure, Practitioner integrity, Profitability, Quality builders, Research and innovation, technology@work, Volume of work and Working conditions.

Pulseº has recently launched two new products that provide an even greater array of accessibility options for use and interpretation of the data.

2.1 PULSE°BUILDING WORK

Pulseºbuilding work is an archive of detailed building permit data available by month, quarter or year, allowing access to in-depth data for each period, locality and type of work selected. It draws on information unique to the Building Commission and is highly desirable for Local Governments, industry suppliers and practitioners to understand the spatial distribution and type of buildings in their municipalities and across the State.

2.2 PULSE°BEAT

Puseºbeat is an on-line analysis tool where custom made reports can be created using the building industry data within pulseº (including pulseºbuilding work data). Analysis including viewing interactions and impacts over time with instantly generated graphs can be done on the screen or the data can be downloaded to an excel spreadsheet with one click for further analysis independent of the website.

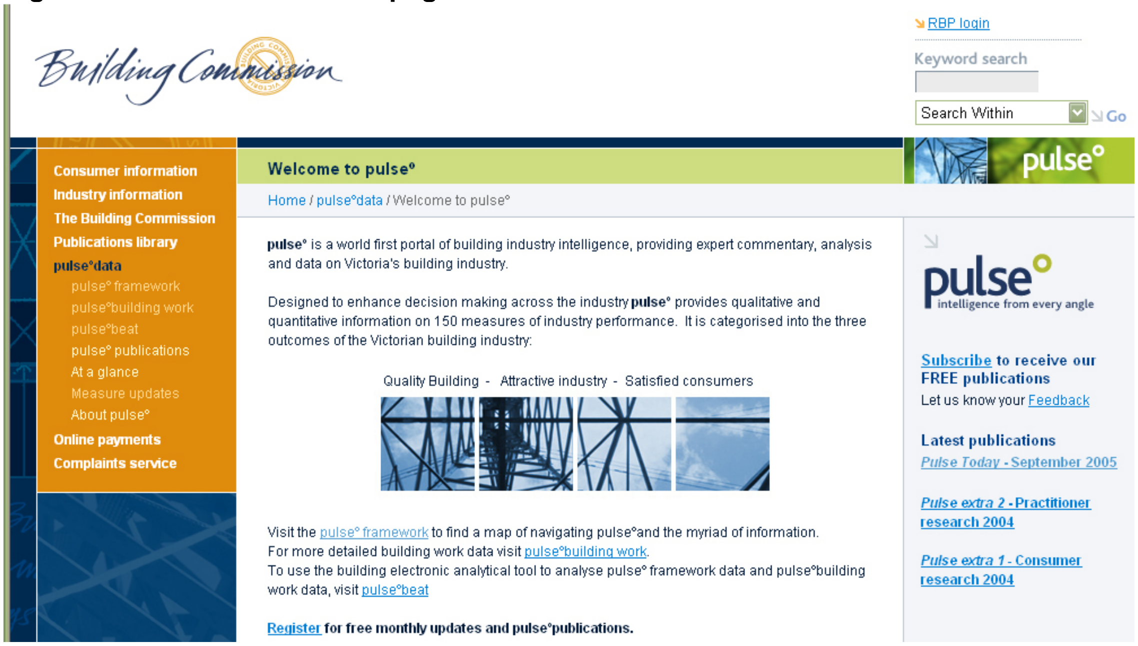
It is acknowledged by pulseº that the building industry does not operate in isolation, therefore the pulse° framework also covers the Economic, Social and Environmental perspectives. These include expert commentaries written on each perspective and some high level data including Consumer Price Index and Interest rates as quick and relevant statistics to making decisions.

3.0 HOW DOES PULSE° WORK?

The centrepiece of pulse° is its website because, contrary to common perceptions, the building industry is now highly computer-literate. Research by the Building Commission last year - and you can find this information at pulse° - showed that 90 per cent of Registered

Building Practitioners use computers in their day-to-day work.[1] Furthermore, over 80 per cent obtain business-related information online, demonstrating the existing demand.[2]

Figure 1 – The website home page



The data is built around a framework that users can navigate through to find the data, graphs and commentary that they are interested in. Alternatively users can create their own reports in pulse°beat.

Figure 2 – The pulse° framework

Quality building	Attractive industry	Satisfied consumers
Q1 - Building standards	A1 - Volume of work	S1 - Community perceptions
Q2 - Quality builders	A2 - Profitability	S2 - Consumer expectations
Q3 - Practitioner integrity	A3 - Industry structure	S3 - Disputes
Q4 - Building control	A4 - Employment profile	S4 - Consumer information
Q5 - Environmental performance	A5 - Working conditions	
	A6 - technology@work	
	A7 - Research and innovation	
	Economic - Social - Environmental	

However, the scope of pulse° is not limited to a website. Some people prefer a publication to easily refer to rather than solely relying on the website. Each year, a summary of all data, graphs, analysis and commentaries contained on the pulse° website is published in printed form, known as pulse° Building Intelligence.

In addition to the pulse° website and annual publication, monthly snapshots of what is happening in the building industry at any moment in time are also part of the pulse°

[1] Building Commission annual Practitioner & Consumer survey, 2004
[2] Ibid

imperative. These monthly updates, known as pulse° today, contain new and updated figures, surveys, analysis and commentaries released during the previous month, and can be obtained through the website, or by setting up automatic email alerts, or mail on request.

The client needs are considered regularly, there is on-line and phone support, plus brochures available to assist users navigating pulseº. The pulseº team openly interacts with their users to encourage feedback and to continuously enhance the website to better suit user's needs. Presentations and live demonstrations have been and continue to be made to all interested parties including Local Governments, Boards, Industry associates and the education sector. Recently the entire site was revamped to give a new look and feel, which makes navigation and access to building industry statistics even easier.

3.1 PULSEº CASE STUDIES

Pulseº works in different ways for different client(s) needs. Currently, the website has approximately 50 visits per workday and nearly 800 registered users. Pulseº anticipates that this level will grow by at least 50 per cent over the next twelve months, as awareness is spread across the industry. The registered users of pulseº provide an understanding of who is using the information. Of those that have been categorised, 34 per cent are building industry employees, members and suppliers, 16 per cent are Registered Building Practitioners, 15 per cent are industry associates, 12 per cent are from State or Federal Government, 9 per cent are Local Government employees, and the Media make up three per cent. Registration is free and ensures that they receive the monthly update pulseº today and all other publications automatically.

Feedback from users has indicated that the data is well used and accepted by all areas of the industry. For instance, suppliers, building businesses and individual Registered Building Practitioners have accessed pulseºdata to assess the feasibility of establishing business in a particular area. The information available is both specific and general, it covers the type of work that they are looking for, employment rates, the number of Registered Building Practitioners in each category, their attitudes, and how they view the future profitability in the market, along with technology use figures and their acceptance of research and innovation, to name just a few measures. This information forms a solid base for a decision of whether the market would be profitable and worthwhile entering, and some ideas on the scope and how to penetrate.

Pulseº has also been used by the Commercial building sector to keep updated with information like Work Cover and occupational health and safety issues, on top of market trends. Pulseº provides the information that is used to benchmark performance and identify areas for improvement, without the need to spend a lot of time tracking it down. The rate of worker's compensation claims, Registered Building Practitioners attitudes towards occupational health and safety procedures and the number and value of other commercial permits being issued to other companies for work not being carried out by them from pulseº is all used as benchmarks to assess individual performance within the industry.

The feedback from Local Government indicates that they find the website a convenient source of the information they require for decision-making and strategic planning. Building activity and it's flow on effects for employment and infrastructure needs to be monitored, and pulseº tells Councils where the permits are being issued and for what type of work, it assists them with their planning. Pulseº has an archive of in-depth building work data in each municipality back to 1998, by type of work, by use and by status of issuer. Local Governments use pulseº to compare their own municipality's building work to neighbouring and other municipalities, information that was hard to obtain before, but very valuable in painting the local economy's picture.

Registered or prospective Registered Building Practitioners including students have used pulse° to better understand the industry that they are in. Pulse°data contains information on the building industry structure, the benefits both Consumers and Practitioners see from being a Registered Practitioner, what type of Registered Building Practitioners there are, how many students are in training, the average income, the number and type of disputes occurring, and the number of hours spent on Continuing Professional Development. Users can also obtain a feel of consumer expectations and behaviour before, during and after the building contract, and the way that they sort out disputes or concerns they may have with their builder.

Anyone interested, regardless of their analytical skills, can access information on the building industry from the one website. Using the pulse°beat feature, users can create their own reports to do their own analysis specific to their needs. For example, pulse°beat can show the impact of the measures upon each other and does the research on the screen by indexing the numbers to show the interaction over time. The raw data is also displayed on the screen and can be exported to excel for further analysis or for inclusion in reports.

Pulse° means different things to different users. Some users may use one figure, others may utilise many of the data sets along with the commentary and analysis, whilst others can create their own reports using pulse°beat. Its capabilities and use depend on the individual client's need.

4.0 WHY IS PULSE° SUCH AN INNOVATIVE PROJECT?

Pulse° is a world first collation of so many diverse and valuable pieces of information about the building industry. It combines statistics with commentary and analysis to deliver unique and timely building intelligence directly into the hands of the building industry, improving its decision-making practices, in a variety of ways to suit all users.

Pulse° is easy to use, suiting all sectors and practitioners in the building industry, from homebuilders to multi-billion dollar property developers and industry analysts and the data extracts can be customised for each user's requirements. It provides the most up-to-date intelligence on the building industry, aiding users to make better-informed decisions.

Pulse° is not static, but a living, changing website, the content and format can be changed as industry feedback is received and new data is released.

Pulse° is up to date information in one place for everyone to access for free. The expense to collate and analyse would be prohibitive to smaller companies to pursue, however through the Building Commission's demonstration of leadership, and response of the expressed needs of its stakeholders, it is now available to all. The time and effort of pulse° users can be spent building a better-built environment through well-informed decision-making.

FACILITIES MANAGEMENT

Refereed Paper

FM SERVICE QUALITY INDICATORS - BENEFITTING SUPPLIER AND CUSTOMER

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ABSTRACT

The main objective of the Service Quality Indicator research project is to identify more objective service quality indicators that are important to service productivity, consequently leading to improved service delivery and higher customer satisfaction, and ultimately increased profitability for both suppliers and receivers of FM services.

The research will focus on cleaning, catering and security, and answer the following:
- What quality dimensions are important for supplier performance?
- What quality dimensions are important for customer satisfaction?
- Which quality dimensions are beneficial to both supplier and customer?

Answering these questions will involve three steps. Firstly, in order to make quality a measured output of service productivity, supplier perceptions on various service quality variables are to be compared with their business performance. Secondly, in order to make quality a measured output customer satisfaction, customer perceptions and expectations on the same quality variables are to be captured. Finally, by combining the outcomes of the first two steps, we can derive mutual beneficial service quality indicators.

The expected results from the research in progress, based on the current findings include: a gap between supplier and customer perceived service quality - as what is beneficial to the supplier is not always beneficial to the customer; the service quality variables will be different for each of the services reviewed - cleaning, catering and security; and the expected overlap between the service quality variables can lead to improved service delivery - the front of house service is one example of this issue.

Keywords: Facilities Management, Service quality, Supplier performance, Customer satisfaction, Productivity analysis

1 INTRODUCTION AND OBJECTIVES

While quality's significance for a firm's competitive position in the marketplace has been emphasised for years, the contribution of quality to business performance has been largely unexplored and the gap between supplier and customer perceived quality is still to be closed. Therefore it is important to examine whether and how quality affects supplier profitability as well as how it affects customer satisfaction. The problem with services however, is that especially the qualitative outputs of the productivity equation are intangible. Contrary to manufacturing, where it is relatively easy to measure for example the conformance of an end-product, much of the quality in services is in the eye of the customer. Subsequently, data on service quality is to be obtained through the customer and by observations of the process and/or the results.

Within the UK business support services sector, outsourced services continue to expand within both the public and private sector. Within the public sector Central Government guidelines on competitive tendering and Private Finance Initiatives are key drivers for outsourcing. Within the private sector the drivers include: reducing fixed costs, increasing labour flexibility, and securing scarce skill resources. Most recently the UK investment banks have identified facility management as a significant business activity within the support services sector. Their reports outline the key players and their performance within the £150 billion support services market sector in the UK. The support services sector in general attracts investors because it has outperformed the FTSE all-share index by 29% over the last few years. This economic growth is described from various perspectives. These sector reports describe various facets of the facility management market depending upon the particular emphasis such as; outsourced services (Deutsche Bank, 2001), total facilities management (Deutsche Bank, 2003), or infrastructure services (Foster, 2001). For the financial community, facility management is a significant part of the support services sector. By taking these support services out of the organisation's direct control the issue of service quality becomes a more complex issue to manage. In addition, the emphasis in the management literature is predominantly one based on a manufacturing perspective. This manufacturing perspective excludes the unique nature of many services not least of which is the importance of the customer in the service process as co-producer. It is service quality from a service management perspective that is being addressed in this research. Within the UK market this is an increasingly important topic to both the public and private sector as they pass control over to suppliers within these areas. Those most often outsourced are cleaning, catering and security and these are the focus of this particular research into service quality.

1.1 DEFINING SERVICE QUALITY

Although supplier strategies and customer decisions are still extensively driven by price, service quality variables such as reliability and reputation are believed to become more and more important. The focus of research therefore will be on service quality and to simplify the discussion, we will lump all non-price attributes into the single dimension called 'service quality' - any attribute that increases the demand for that service at a fixed price[1].

1.2 RESEARCH FOCUS AND QUESTIONS

The research will focus on cleaning, catering and security, and answer the following:

- What quality dimensions are important for supplier performance?
- What quality dimensions are important for customer satisfaction?
- Which quality dimensions are beneficial to both supplier and customer?

1.3 RESEARCH OBJECTIVES

Ultimately, the outcome of the research should lead to:
More objective service quality indicators, consequently leading to:

- Improved service delivery
- Higher customer satisfaction
- Increased profitability for both supplier and customer

2 THE SERVICE PRODUCTIVITY CONCEPT

While productivity measures for manufacturing are widely understood and used, productivity measures specific for services have developed more slowly (Mills *et al.*, 1983). This slower development of productivity measures for services has been attributed to intangibility (Drucker, 1974), labour intensity (Flipo, 1988) and complexity (Schmenner, 1986). Ignoring these characteristics, productivity management in the service industry has for too long been dominated by the logic of manufacturing (which is less complex, less labour intensive and less intangible). While comparing productivity between service and manufacturing operations, one of the basic claims has been that the special characteristics of services demand a more holistic approach including a customer-orientation to productivity (e.g. Grönroos, 2000).

2.1 CONCEPTUAL UNDERPINNINGS

Because the current debate on service productivity is in its infancy, we must start by elucidating the conceptual underpinnings of productivity. First we have to decide what we are trying to capture before making any attempt to measure, and a meaningful definition of productivity has to keep the concept analytically distinct from related concepts like effectiveness and efficiency (Veld, 1998 and Vuorinen *et al.*, 1998).

Organisational effectiveness

The classic criterion to evaluate the functioning of an organisation is effectiveness. Effectiveness refers to what extent the actual result (output in quality and quantity) corresponds to the aimed result. It is expressed as the following equation:

$$\frac{\text{actual result (output in quantity and quality)}}{\text{aimed result (output in quantity and quality)}}$$

Note that the closer the actual result approaches the beforehand-aimed result, the more the effectiveness of an organization increases. If the actual result is better or more than the aimed result, the transformation process has a so-called ‘overshoot’. If the actual result is worse or less than the aimed result, it has an ‘undershoot’. In both cases the organisation is not optimally effective.

Organisational efficiency

During the first half of the 20th century, efficiency became more and more important. Efficiency refers to the ratio between the aimed resource use (input in people and means) and the actual resource use, in order to transform an input to an output. A formal definition is:

$$\frac{\text{aimed resource use (input in quantity and quality)}}{\text{actual resource use (input in quantity and quality)}}$$

According to this definition, the efficiency of an organisation increases, as the actual resource use is lower than the aimed resource use. Therefore, to increase organisational efficiency, it is important to reduce the use of resources as much as possible.

Organisational productivity
Increasing prosperity led to a new criterion for organisational focus: productivity. Productivity refers to the ratio between the actual result of the transformation process and the actual resource use. A proper definition is[2]:

$$\frac{\text{actual result (output in quantity and quality)}}{\text{actual resource use (input in quantity and quality)}}$$

Based on this definition, we can conclude that the organisational productivity is optimal when an organisation produces as great a result as possible at the lowest possible resource use. However, a so-called 'overshoot' or 'undershoot' is still not desirable. So at the level of an organisation as a whole, we can optimise the productivity through steering at efficiency, thus by reducing the actual resource use as much as possible (van Ree, 2002).

2.2 QUANTITY AND QUALITY ASPECTS

Although many authors still regard productivity and quality as separate concepts (e.g. Heskett *et al.*, 1994), several researchers (e.g. Grönroos, 2000) argue that quality and productivity cannot be dealt with separately in the case of services. Consequently, there seems to be a growing need for a thorough analysis of the productivity concept in the context of services.

Quantity aspects
Regarding the quantity aspects of service productivity, the input factors of services are the same means of production as in manufacturing: people and means. Owing to the labour-intensiveness of service production, labour is key input to productivity as salaries, commissions and social expenses can account for more than 80 per cent of operating costs. The output of the quantity dimension in services can be based on service volume - to be increased by selling a larger variety of services to the existing customers or attracting new customer segments.

Quality aspects
The quality aspect is a dimension that is difficult to define objectively. In the case of manufacturing products, the quality dimension has usually been operationalised as conformance to specifications and as actual product performance. However, this notion of quality has been regarded as inadequate in the case of services. The input of the quality dimension is depending on employee expertise and skills and to certain extends the facilities. The output of the quality dimension in services can be based on customer satisfaction.

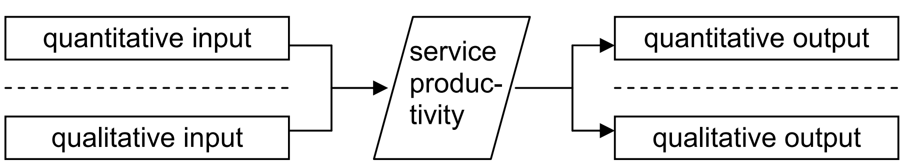


Figure 1 The content of service productivity (Vuorinen *et al.*, 1998)

It is important to recognise that the way customers perceive service and how service delivery is organised cannot be considered in isolation from each other. Most elements of the quantity and quality dimensions of service productivity are interrelated. And although difficult to analyse each element one by one in logical order, it is important to understand the elements constituting a whole.

2.3 THE SERVICE PROFIT CHAIN

The widely accepted service profit chain establishes the links between profitability, external service value and internal service quality. In the service profit chain, service quality plays a dominant - not to say vital - role. There are seven fundamental propositions that form the links of the chain (Heskett *et al.* (1994, 1997): customer loyalty drives profitability and growth; customer satisfaction drives customer loyalty; value drives customer satisfaction; employee productivity drives value; employee loyalty drives productivity; employee satisfaction drives loyalty, and internal quality drives employee satisfaction.

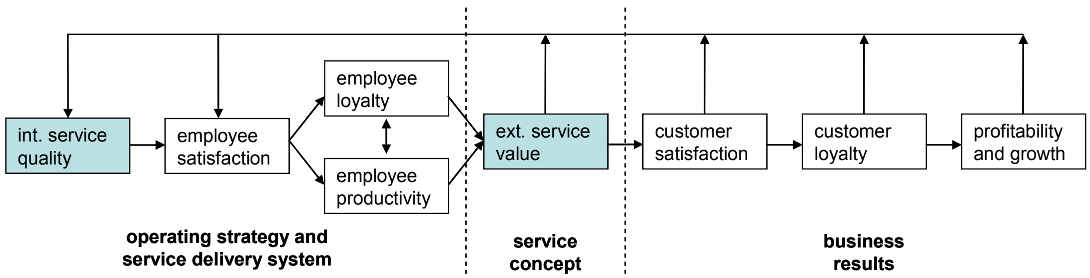


Figure 2 The service profit chain (Heskett *et al.*, 1994)

As stated before, the way customers perceive service and how service delivery is organised are not to be considered in isolation form each other. By combining the chains of supplier and customer, we find that external service value in the supplier chain becomes part of the internal service quality in the customer chain. In addition, employee satisfaction in the customer chain becomes part of customer satisfaction in the supplier chain.

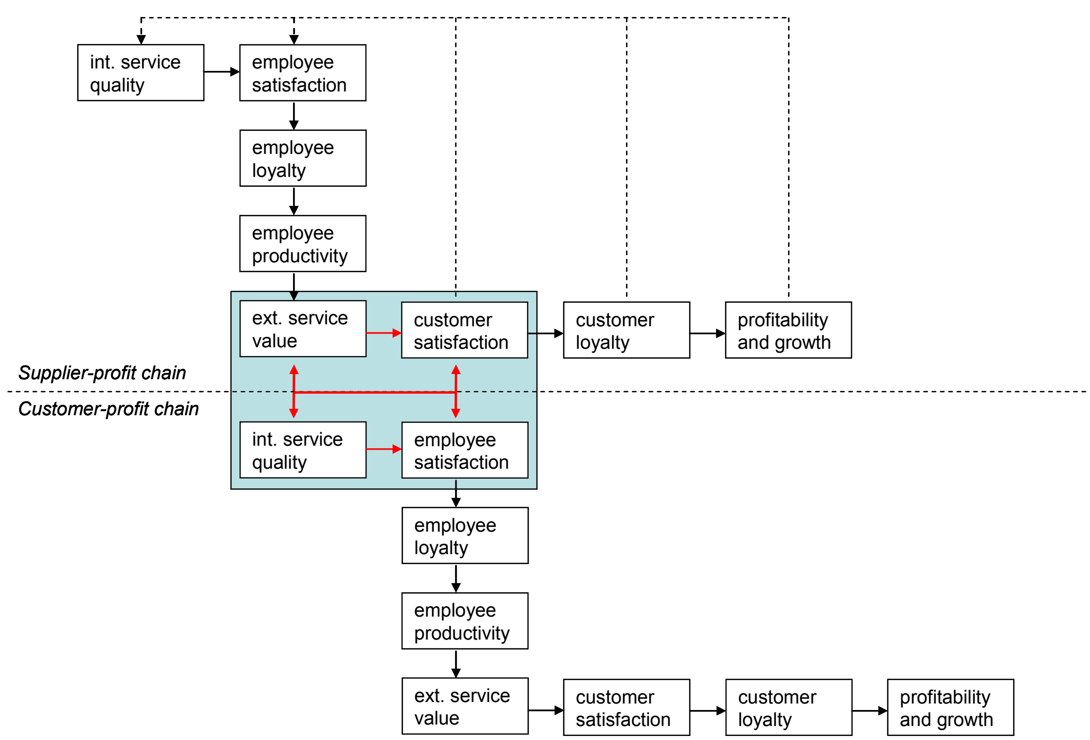


Figure 3 Focus of the research is on the discrepancies at the meeting point of both chains

On the supplier side, high-quality FM services have the potential to improve customer satisfaction and loyalty, leading to winning market share, enhancing sales and barriers to entry. On the client side, high-quality FM services have the potential to consecutively improve employee satisfaction, loyalty and productivity, ultimately leading to profitability and growth.

3 THE VALUE ADDING FACILITIES CONCEPT

Stiffening competition, caused by an increasingly turbulent contextual and transactional environment, forces many organisations to re-examine every way in which they can improve their performance. As a substantial part of the resources used during the transformation from input to output within office-based organisations, facilities can have a significant impact on organisational performance (van Ree, 2002).

3.1 EFFICIENCY AND EFFECTIVENESS

Currently there are approximately 7 million workers are employed in office buildings across the United Kingdom; this is over 25 percent of the active labour force (www.statistics.gov.uk, 2005). The primary process in office-based organisations consists of receiving (input), generating, interpreting, processing, editing, managing (transformation), and providing (output) information (Wentink and Zanders, 1985). In this process the actual transformation is established through co-ordinated interaction between the production factors: people and means.

If an organisation is guided by profitability, the transformation process should be effective as well as efficient at the same time. If this is the case, we can speak of a fruitful or productive process. As a substantial part of the resources used during the transformation from input to output within office-based organisations, facilities (accommodation, services and resources, Information Technology and Facilities Management) can have a significant impact on organisational performance.

Nowadays, there are two important approaches in which facilities can contribute to organisational performance:

(1) Achieving greater efficiency - by reducing total facilities costs; and
(2) Achieving greater effectiveness - by optimally supporting employee productivity

In order to maximise the cumulative impact of both approaches, and to avoid a negative impact of one approach on the other, a transparent decision support structure with clear definitions is desirable.

3.2 THE ADDED VALUE OF FACILITIES

Being part of the resources used during the transformation from input to output, facilities can influence organisational efficiency and therefore organisational productivity. By relating the accommodation to the organisational performance criteria, we can tell something about its quality.

Effective facilities

Given the fact that the main goal of facilities are to support the productivity of the accommodated individuals, and that effectiveness refers to the ratio between actual and aimed result or output, a proper definition of effective accommodation is:

$$\frac{\text{actual contribution to individual productivity}}{\text{aimed contribution to individual productivity}}:$$

Note that, contrary to organisational effectiveness, the effectiveness of facilities increases if the actual contribution to the individual productivity exceeds the aimed contribution. Although this is a so-called ‘overshoot’, it is contributing to the organisational efficiency because the number of people needed in the transformation process from input to output could be reduced. However, if the actual contribution turns out to be lower than the aimed contribution, we have to deal with an ‘undershoot’ - the facilities are not optimally effective. Besides that, it might turn out that more people are needed to feed the transformation process, which has a negative impact on organisational efficiency.

Efficient facilities
As stated before, efficiency is the ratio between the aimed resource use and the actual resource used, in order to transform an input to an output. From this point of view we can consider the facilities as a part of the total resource use. A formal definition is:

$$\frac{\text{aimed occupancy cost}}{\text{actual occupancy cost}}$$

As in the definition of organisational efficiency, the efficiency of the facilities increases if the actual occupancy costs are lower than the aimed occupancy costs. So the actual occupancy costs should be reduced as much as possible to create optimal efficiency. Increasing the efficiency of the facilities however can harm its’ effectiveness. By approaching facilities from a productive point of view, we can prevent this.

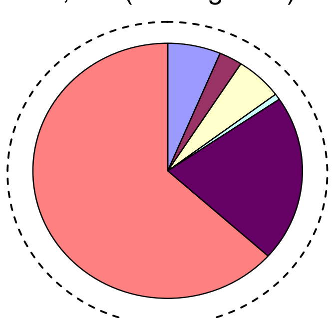
Productive facilities
As stated before, productivity refers to the ratio between effectiveness and efficiency. According to the definitions of effective and efficient facilities, we can define productive facilities as:

$$\frac{\text{actual contribution to individual productivity}}{\text{actual occupancy cost:}}$$

Based on this definition we can state that facilities become optimally productive when the contribution to the individual productivity is as high as possible at the lowest possible occupancy costs. Its productivity also increases when the individual productivity increases with the same occupancy costs, or when the occupancy costs decrease at the same level of individual productivity. More important, by approaching facilities from a productive point of view, we gain insight into the impact of efficiency on effectiveness and vice versa, thus making it controllable.

3.3 FROM THEORY TO PRACTICE

The average running costs of a workplace in an office building, including operation and maintenance, are slightly over £6,400 per year. The yearly costs of labour, including benefits, are around £44,000 per FTE. Together with the costs of Information Technology (£3,570), the total annual cost of an office employee averages £64,000. If an organisation is guided by profitability, an employee should bring in at least 1.5 times his or her annual costs, which equals £95,000 (see Figure 4).



Accommodation	£ 4.100
Services and Resources	£ 1.700
Information Technology	£ 3.550
Facilities Management	£ 650
Benefits	£ 13.500
Salary and Wages	£ 40.500
Employee Costs	**£ 64.000**
Desired Profit	*£ 95.000*

Figure 4 The annual costs and desired profit of an average white-collar employee in the UK

Based on Figure 4, the services and resources of an organisation can be made more efficient by looking for possibilities to reduce the £1,700 a year spent on them. More effective services and resources means optimally supporting employee productivity, which corresponds with increasing the £95,000 desired profit per employee. The problem, however, is that focusing on the efficiency might have a negative impact on the effectiveness of these services and vice versa. Therefore, the focus should be on establishing productive service delivery.

Due to the fact that the £95,000 corresponding to the desired profit is much higher than the £1,700 spent on services and resources, the most intelligent way to make them more productive is to focus on doing more with a proportionately smaller increase in resources consumed. Following this reasoning, an over-investment of even 10 percent on service and resources, equalising £170, will already be cost-justified if employee productivity increases just 0.2 per cent, which is less then half a day of labour per year or 1 minute per day.

The biggest contribution to total organisational performance however, can be made if we are able to make service delivery more efficient and effective at the same time.

4 CLASSIFICATION FOR MEASUREMENT PURPOSES

Productivity measures express relationships between the outcomes or outputs of services processes and the resources or inputs required to operate them. Having appropriate definitions of outputs and inputs is critical to meaningful productivity analysis. Without the right specifications of inputs and outputs derived from careful process analysis and matched with the right measurement techniques productivity measurement in services cannot succeed (McLaughlin and Coffey, 1990).

4.1 MEASUREMENT PROBLEMS

Both the quantitative and the qualitative input and output indicators for a service delivery process must be quantifiable if service productivity is to be measured. The problem with services however is that most of the qualitative inputs and outputs are intangible - and the intangible aspects of service delivery processes - depending on consumer involvement and customisation[3] - make productivity measurement difficult (Gadrey, 1988).

Contrary to manufacturing, where it is relatively easy to measure for example the conformance or durability of an end-product, much of the end-product quality in services is in the eye of the customer (customer perceived quality). Subsequently, data on service quality is to be obtained through the customer or by observations of the process and/or the results. Research on customer perceptions of services would enable us to capture more of quality in an output, ensuring that the attributes being measured are closely linked to customer desires. Moreover, services have many directly observable attributes in terms of waiting time and speed of delivery, physical characteristics (e.g. cleanliness, temperature and colour), expertise, courtesy, etc.

All in all, intangibility should not be a reason to avoid productivity analysis, but form a challenge to ‘tangibilise’ the intangibles or to establish proxies. In order to measure the right things right, we must first identify the productivity measures available for services and develop a classification scheme for facility services and resources in order to determine which measurement approach is appropriate for which service.

4.2 CURRENT PRODUCTIVITY MEASURES

Currently, a variety of productivity measures are available for services (McLaughlin and Coffey, 1990). Derived from traditional manufacturing, methods such as output-input ratios and work measurement methods are available. The problem however, is that output-input ratios are frequently criticised for their narrowness and that work measurement methods are most appropriate to services where the outputs and inputs are simple.

Within the aggregate comparative methods, the most commonly used measures are statistical comparisons and deterministic models. Although already more useful for service productivity analysis, statistical comparisons require a rather large numbers of units are required for statistical significance, and deterministic models (e.g. Data Envelopment Analysis) are better suited to diagnosis than to control.

Among other methods we find practice variation studies and quality plus techniques, of which the latter seems the most interesting, because it attempts to make quality a measured output of the service. The Service Assessment Matrix (SAM) is one interesting approach developed to incorporate aspects of quality into service productivity measurement. In this approach potentially 'productive' service quality criteria are linked to more traditional productivity measures (e.g. output/input ratios) through a matrix to test interrelations.

4.3 CLASSIFICATION OF FM SERVICES

Customer involvement and customisation have often been cited as key characteristics of services. A number of authors have suggested them as the classification variables for services (Schmenner, 1986; Chase, 1981; Maister and Lovelock, 1982). Using those two dimensions, the measurability of service quality decreases when customer involvement and/or customisation increases. Service quality of services with high customer involvement and high customisation is hardly measurable. Here quality enhancement or improvement ask for commitment from the people involved (attitude) and their relation (interaction), which is depending on a constructive dialogue between contractor and client (Vinkenburg, 1995).

In the research to be performed we will focus on cleaning, catering and security. The main reason for this focus is that productivity measurement on these services is relatively easy due to low customer involvement and low customisation. A second reason is that these services are daily experienced by the customer and therefore have a relatively high impact on total perceived facility service quality.

5 FM SERVICE QUALITY CASE STUDIES

As in manufacturing, good process analysis precedes good productivity analysis: one has to have a clear picture of the service process itself before undertaking any productivity measurement.

5.1 PROCEDURE FOR SERVICE PRODUCTIVITY ANALYSIS

With a classification scheme and knowledge of available measurement techniques in hand, we can consider how one can go about tackling productivity issues in services. We suggest the following (after McLaughlin and Coffey, 1990):

1. First of all, one should specify the reason for investigating service productivity.
2. Then analyse the service delivery system in place and decompose it into its process steps/stages.
3. Next specify the service characteristics that are of strategic importance at each service process step/stage.
4. Then specify quantitative inputs (and measures), qualitative inputs (and measures or proxies), quantitative outputs (and measures), qualitative outputs (and measures or proxies), as well as limits of trade-offs.
5. Select the methods of productivity measurement which seems most appropriate to the analytical objectives.

Besides the suggested steps it is important to involve implementers[4] all along the way - not least because staff acceptance of any proposed productivity measures is critical to their ability to enhance productivity.

5.2 CASE STUDIES

As stated before, quality's significance for a firm's competitive position in the marketplace has been emphasised for years, but the contribution of quality to business performance has been largely unexplored and the gap between supplier and customer perceived quality is still to be closed. Examining whether and how quality affects firm performance is an important issue for businesses, both on the supply and the demand side.

The case studies will focus on cleaning, catering and security. Customer perceptions on these services will be captured through surveying employees of the Royal Bank of Scotland. Supplier perceptions on cleaning will be obtained through interviewing Lancaster Cleaning and Mowlem Pall Mall. Perceptions on catering will be captured by interviews at Compass Group and perceptions on security by interviews at Group 4 Securicor. To obtain larger numbers for statistical significance, market surveys within the cleaning, catering and security market are to be held.

The Service Quality Indicator project started in August 2005 and will be disseminated according plan in spring 2006. The research is a joint effort between the Workplace Innovation Centre (University College London) and Group Property (Royal Bank of Scotland) as well as Lancaster Cleaning, Mowlem Pall Mall, Compass Group and Group 4 Securicor.

5.3 RESEARCH METHODS

By using quality plus techniques (Service Assessment Matrix), quality can become a measured output of the service delivery process. Incorporating customers' and suppliers' perspectives, this will involve:

- Identifying perceived service quality variables (group interviews)
- Capturing supplier perceptions (supplier surveys)
- Measuring supplier business performance (market surveys)
- Capturing customer perceptions (customer surveys)
- Linking the quality variables to supplier business performance (regression analysis)
- Linking the quality variables to customer perceptions (regression analysis)
- Deriving mutual beneficial service quality indicators from the two regression analyses

By linking quality variables to supplier performance and customer satisfaction the research proposed should lead to clear quality indicators for service delivery concerning cleaning, catering and security.

Group interviews

The group interviews, involving all research participants, are to determine a set of service quality variables that are crucial indicators of service quality and as likely determinants of a firm's market and financial performance. Preliminary service quality variables are: physical characteristics, reliability and trustworthiness, responsiveness and service recovery, professionalism and skills, courtesy and attitude, reputation and credibility, security and assurance, accessibility and flexibility, communication with the customer, and understanding the customer

In addition these interviews are to determine the most important financial measures. Preliminary measures are focussing on market share and profitability ratios: market share, market share growth, profit margin, profit margin growth, sales volume, sales volume growth, return on investment, assets, equity, capital employed and/or sales, and return on investment, assets, equity, capital employed and/or sales growth.

Supplier and market surveys
From the group interviews we will draft a two page questionnaire to be sent out to major cleaning, catering and security firms in the UK. From these questionnaires we are then able to determine the links between Service Quality Variables and organisational performance within each segment through regression analyses.

The service quality variables will be measured against strategic importance on a 7-point scale from “least important” (=1) to “extremely important” (=7) and as performance relative to major competitors on a 7-point scale from “poor” (=-3) to “excellent” (=+3). The financial ratios will be measured objectively on actual values and subjectively on a 7-point scale from “worst in industry” (=1) to “best in industry” (=7).

Customer surveys
From the group interviews we will also draft a customer survey with additional questions under each Service Quality Variable. These questionnaires are firstly to be set out under the RBS employees (and maybe later to other organisations) to determine what customer’ employees see as the most important variables within each segment.

The service quality variables will be measured against service performance as well as two levels of expectations: desired service (what the customer believes the service should be) and adequate service (the minimal level of service acceptable to the customer) on a 7-point scale from “poor” to “excellent”.

Final analysis
By combining the outcomes of the supplier and market surveys with the outcomes of the customer surveys we can finally determine whether there is significant overlap in supplier and customer perceptions and expectations, or that there are discrepancies between the two, which then might ask for a strategic redirection in one or more of the segments.

6 EXPECTED RESULTS AND CONCLUSIONS

At present the research is in progress, but the results from the first interviews are consistent with previous research findings in this area. The interviews have indicated a gap between suppliers’ perceptions and customers’ desires, especially if not both parties were fully involved in the original contract Service Level Agreements for example. Therefore the expected results from this investigation based on the current findings include: a gap between supplier and customer perceived service quality - as what is beneficial to the supplier is not always beneficial to the customer; the service quality variables will be different for each of the services reviewed - cleaning, catering and security; and the expected overlap between the service quality variables can lead to improved service delivery - the front of house service is one example of this issue.

The conclusions from the Service Quality Indicator research project will hopefully underline the continued importance of research work that looks at service operations from a service perspective. The manufacturing paradigms do not always generalise well to the service environment and this project begins to indicate the limitations of taking this manufacturing approach. The project then seeks to provide a number of insights into the service quality framework.

APPENDIX EXAMPLE DATA ANALYSIS

Because the research project on Service Quality Indicators only started two month ago, there is no hard data analysis available yet. With a proposed timeframe of six month and all participants contributing constructively, research finding are to be disseminated in February 2006 and to be presented firstly at the International Conference of the Cooperative Research Centre for Construction Innovation.

Below examples are presented of the data analyses to be performed after the supplier and market surveys.

Business performance measure	Model *p* value	Quality variable	Entry *p* value
Market share	0.032**	reliability and trustworthiness	0.032**
Market share growth	NS	NS	NS
ROI	0.002***	reliability and trustworthiness	0.002***
ROI growth	0.014**	responsiveness and service recovery	0.014**
ROCE	0.008***	professionalism and skill	0.008***
ROCE growth	0.006***	professionalism and skill	0.058*
		courtesy and attitude	0.086*

*** significant at 0.01, ** significant at 0.05, * significant at 0.10
NS = not significant

Figure 5 Example of results of analyses with business performance as dependent variable

From the example above we can conclude that there is a relatively strong link between market share and the quality variable reliability (p = 0.032). In addition, there is a very strong link between ROI and the quality variable reliability (p = 0.002). Also responsiveness, professionalism and courtesy are of positive impact on various business performance measures.

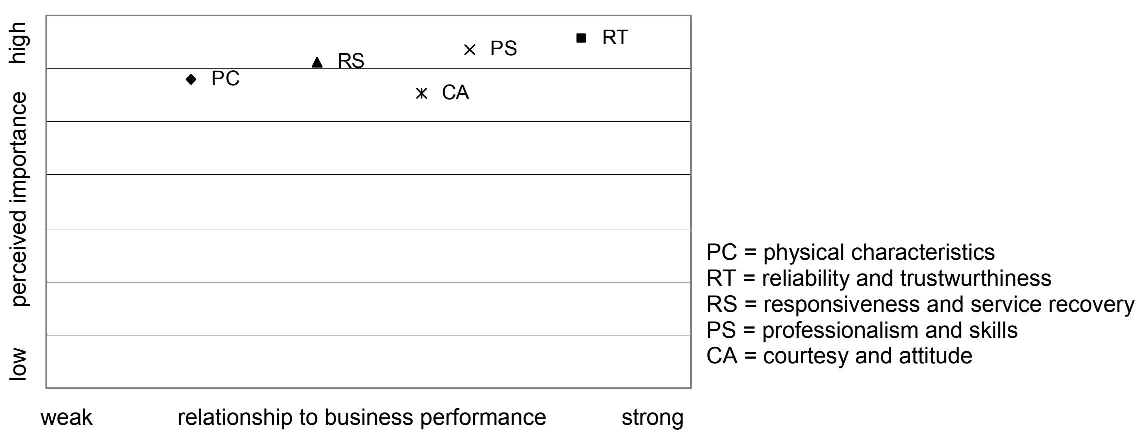
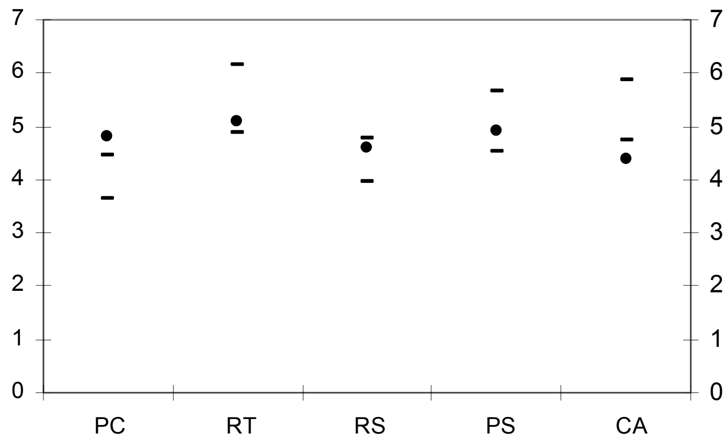


Figure 6 Example of perception-performance gap analysis of quality dimensions

From the example above we can conclude that reliability and professionalism, as perceived, indeed have a strong relationship with overall business performance. Contrary to the perception however, courtesy also has a relatively strong link with overall business performance.

Below an example is presented of the data analyses to be performed after the customer surveys.



PC = physical characteristics
RT = reliability and trustwurthiness
RS = responsiveness and service recovery
PS = professionalism and skills
CA = courtesy and attitude

Note: The dots indicate perceived service. The vertical lines indicate customers' zones of tolerance bounded on the top by their desired service expectations and the bottom by their adequate service expectations.

Figure 7 Example of service quality ratings by customer (RBS employees)

From the example above we can conclude that also customers rate reliability and professionalism as the two most important quality variables to overall service quality. Furthermore we can conclude that the service provider is underperforming on courtesy and over performing at physical characteristics.

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[1] Other working definitions are: 'how consistently the product or service delivered meets or exceeds customers' (external and internal) expectations and needs' (Clark, 1992) or 'the totality of characteristics of an entity that bear on its ability to satisfy stated and implied needs' (BS EN ISO 9000, 2000).

[2] Another often used definition of service productivity is 'the ability of a service organisation to use its inputs for providing services with quality matching the expectations of customers' (cf. Järvinen et al., 1996), but this definition ignores the quantitative output aspects of service productivity.

[3] Also the interpretability of the server from the service, the participation of the client in the process and the subjective role of the client in evaluation contribute to intangibility.

[4] Ideas about *what* changes or opportunities will benefit your business; sponsorship from someone with enough authority to put money or people's time into working on the idea; specialised technical or analytical thinking about the best way to make the idea work; the energy and commitment of all who have to do anything to implement the idea to make it successful (Stankard, 1986).

PROCUREMENT AND RISK MANAGEMENT

Refereed Paper

EFFECTING SUSTAINED INNOVATION IN THE CONSTRUCTION PROCUREMENT PROCESS

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ABSTRACT

There have been numerous studies reviewing factors implicit in the management of building design innovation. There has been less consideration given to the impact of these factors at various stages of the construction procurement process. How innovation is managed at particular stages of this process may have a determinant bearing on the sustainability of the innovation and, subsequently, the effectiveness of the innovation for clients and building users.

The primary objective of this paper is to outline a methodology to investigate the impact of procurement stages on the delivery of a building design innovation. The methodology will encompass a literature-based model through which a pilot study will be subject to analysis using a risk assessment tool called FMEA (Failure Mode and Effect Analysis). The analysis will identify those factors, which heightened risk for the delivery of the innovation. It is hypothesised that there must be more incisive management at the design stage, where there is less pressure from project constraints, in order to sustain the innovation for the life-time of the construction process.

Keywords: Construction innovation, procurement, methodology, management model

1.0 INTRODUCTION

The overwhelming opinion is that, construction is considered a 'lumbering giant', amongst the mainstream profit-generating industries of the national economy (Gann, 2000; Pries and Janszen, 1995); brimming with creative potential to innovate, but unable to sustain this momentum, from project to project. The products of construction are a combination of creative inception, in the design process, and standardised production techniques, in the construction phase. This paradox should produce an internal dynamic, which can generate and sustain innovation (Groak, 1992). However, it has been shown that the divisions between the conceptual stages of design, and the practical stages of construction, can also give rise to long project times, poor quality control and slow piecemeal innovation (Gann, 2000). It is the client as primary stakeholder who ultimately bears the effects of this deficiency and, subsequently, is reluctant to advance innovation within future projects. Hence, it is contended that innovation is not only failing to sustain the lifetime of projects but also from project to project. Therefore, a sustained innovation is illusive.

1.1 SUSTAINABLE INNOVATION

Many theorists speak of achieving 'successful' innovation. However, the definition of innovation success has not been clearly considered and has been advanced in terms of increased economic growth and productivity (Schmookler, 1952; Schumpeter, 1934), social and competitive benefits (Seaden, 1996), as well as improved reputation and ease of work (Slaughter, 1998). This study defines successful innovation as the ability to sustain in form and function the duration of the procurement process. Many new technologies may be successfully introduced into the design of a project but, due to the pressure of constraints, they fail to be fully implemented into the final building. Dulaimi (2002) found that, in order for an innovation to be successful, there must be minimal constraints present during the contract (Dulaimi *et al.,* , 2002). Similarly, according to Goldratt's, Theory of Constraints (Goldratt*, et al.* 2000), 'the weakest link defines the maximum performance of the process'. Therefore, if the complexity of a building design innovation were a programme-defining issue, then the innovation would be considered a weak link, and steps would need to be taken to 'strengthen the link or break the constraint'. The authors of this study argue that adequate consideration has not been given in the literature to the management of innovation at various stages of the procurement process. The primary objective of this paper is to propose a methodology to investigate the impact of procurement constraints on the delivery of a *project-based, consultant-led building design innovation.* The study attempts to ascertain at which stages in the procurement process does such an innovation need to be 'strengthened' in order to sustain. A Pilot study is carried out to test the validity of the methodology and inform the ongoing research.

2.0 INNOVATION

'New technology' is a product, process or system that a company has not previously used in their construction operations (Laborde and Sanvido, 1994) and an 'invention' is the idea for that new technology (Rogers, 1983). Whilst invention is the necessary pre-requisite to develop new technologies 'innovation' is the first commercial transaction involving the technology (Freeman, 1974; Myers*, et al.* 1969). Innovation is the act of seeking, recognising and implementing a new technology as opposed to the creative impetus alone. Slaughter (1998) has described invention as the 'detailed design' of a new technology; therefore it is the implementation of the invention that brings the innovation into being. It is proposed that the *architectural design* of a building project incorporates the seed of many innovations. It is these innovations that are the focus of this study, and their subsequent impact on the design of the completed building. Some examples of this type of innovation are Dichroic film, a polyester film originally used as an attractive packaging material for the cosmetics industry, which creates psychedelic colour effects when applied onto glass facades. Litracon, the recently devised adaptation to the concrete block, which incorporates optic fibres and renders the block transparent, and the magnetic floor tile, by Dalsouple, which considerably reduces onsite labour, and cuts maintenance costs. Adversely, there have been a series of recent high profile failures of such innovations. The collapse of the glass roof at the Swiss Re building, London (Building Design, 2005) and the ‘swaying’ failure of the London Millennium bridge (Guardian, 2000) have been cited as prime dissuaders of the adoption of new technologies by consultants.

2.1 PROJECT-BASED INNOVATION

Project-based innovation takes place within the parameters of a construction project. It may be a new technology, which has been adopted into the project to suit the project requirements; ‘adoptive innovation’ (Gann, 1997; Quigley, 1982), or it may be innovation generated from within the project often referred to ‘practitioner-research’ (Groak, 1992; Slaughter, 1993; Winch, 1998). Winch (1998) considers both types ‘a priori’ and of equal validity. The context of building projects is temporal as are its alliances (Slaughter, 1998). This may be part of the reason why project-based innovation has not been widely researched; there is a small window of opportunity to carry out live research and post-project evaluations are uncommon (Tatum, 1987; Yean Yng Ling, 2003). In researching project-based innovation it is necessary to capture both the lessons of retrospective projects as well as the results of live projects. This study will attempt to do both.

2.2 THE INNOVATION PROCESS

Marquis’ 1968 study is still viewed by many researchers as a seminal piece of work into the process of innovation. His work was drawn from investigation into 500 ‘incremental’ innovations from a range of industries. He set out a six-stage process in the search to determine the characteristics of ‘successful’ innovations (Fig.01). Whilst Marquis implied a linear process in his diagram he accepted that innovation is not sequential by nature. This is also true for the process of design in which the stages are often overlapping, interconnected and even cyclical (Lawson, 1997). In this respect, the process of innovation and design are similar and therefore the process of architectural design would appear to lend itself to the incorporation of an innovation. However, architectural design is also fused with the rigid process of construction that is the anthesis of this free-flowing, chaotic process (Quinn, 1985). This is the core of the contradiction in introducing an innovation into the procurement process.

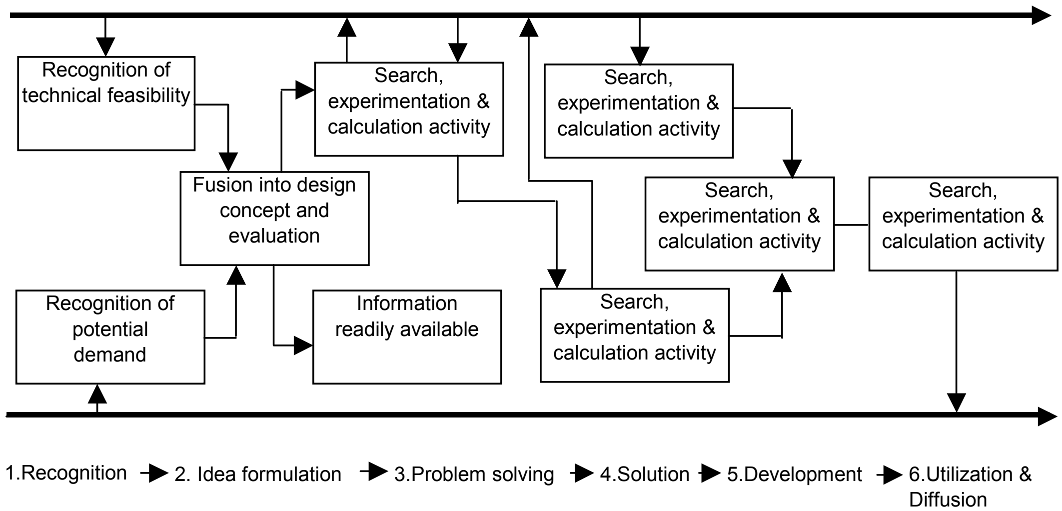

Fig.01 Model of the process of innovation (Marquis, 1968)

Following Marquis, a number of studies were carried out to adapt this process to construction and develop frameworks for managing successful innovation (Tatum, 1987; Winch, 1998; Slaughter, 2000). Winch (1998) outlined the contextual processes that need to be managed for successful innovation and Tatum's (1987) process of innovation was a reactive model for use on construction projects. Slaughter's (2000) cyclical model drew from these previous models as well as from general literature studies. In doing so she sought to highlight the aspects relevant for construction innovations, and their implementation into the construction project (Fig.02).

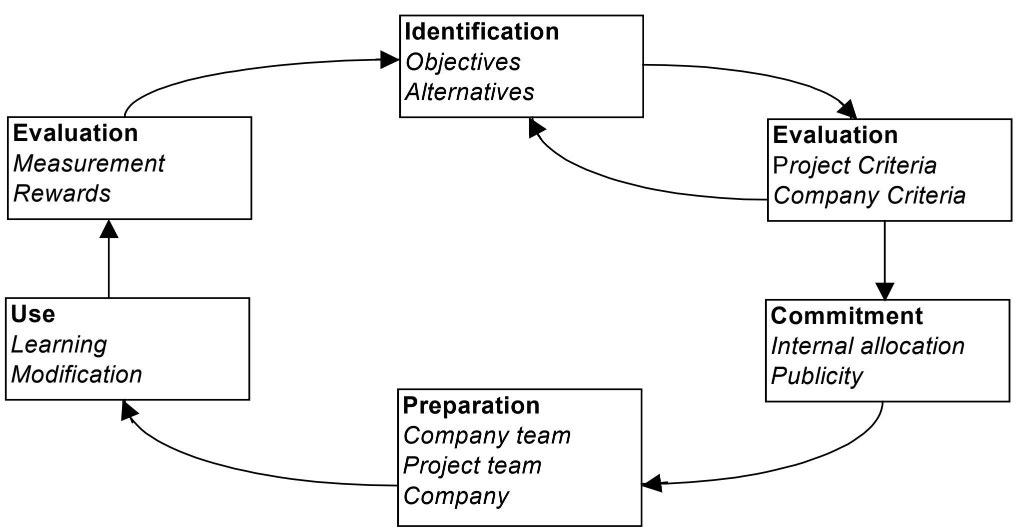

Fig.02 Implementation stages for innovations (Slaughter, 2000)

Whilst all of these studies have expanded our understanding of the management of innovation within the project, they have not attempted to identify the effect of the procurement process on the management of innovation. Procurement of buildings has traditionally followed a serial, sequential model from inception through to completion (Cooper*, et al.* 2005). The Plan of Work stages, formulated by the Royal Institute of British Architects (RIBA, 1995) is a widely recognised framework of procurement which sets out the activities of the procurement process from appraisal of the client requirements through to post-construction evaluation (Fig.03).

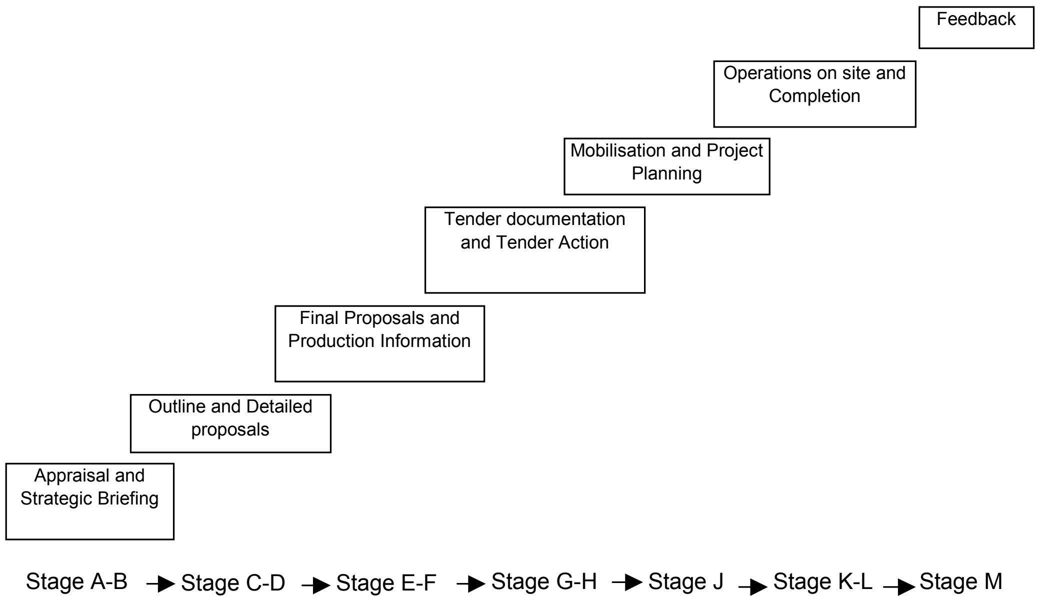

Fig.03 The RIBA Plan of Work (after, RIBA, 1999)

This form of procurement is often referred to as a 'separated system' due to the separation of the responsibility for the design of the project, from that of its construction (Masterman, 2002). However, more recent methods of procurement have sought to integrate the stages of design and construction to facilitate better client participation, and contractor integration. Such forms of procurement are known as 'integrated systems' eg: Design and Build (D&B). For the purposes of this paper it is intended to devise a generic procurement process incorporating both separated and integrated forms of procurement.

3.0 OVERALL RESEARCH METHODOLOGY

This paper forms part of a wider piece of research into sustaining innovation in the procurement process. The wider research methodology is outlined below and its stages are described (see Fig.04). In this paper a pilot study from Case Study Group A is carried out to test the validity of this research methodology and to inform the wider research.

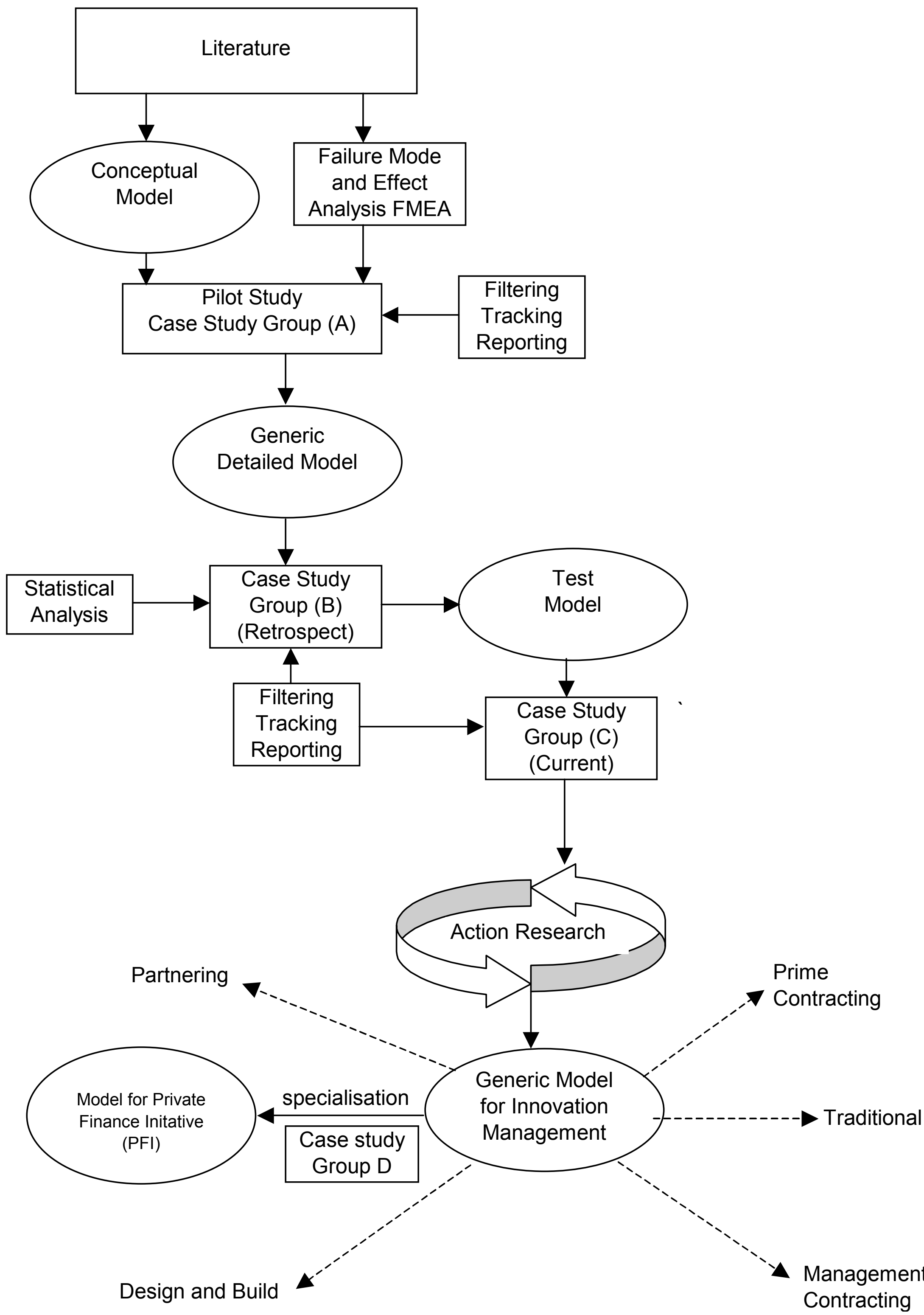

Fig.04 Research Methodology for the Development of an Innovation Management Model for the Construction Procurement Process.

3.1 CONCEPT MODEL

A literature review is carried out on the areas of innovation, innovation management and procurement. From this a Concept Model is compiled to represent the correlations between:

a) The process of innovation
b) The management of innovation
c) The generic procurement process

This Concept Model presents a functional correlation between three literature-based models; namely, a generic procurement model formulated from the RIBA Work Stages and the Design and Build form of contract (CD 81), Marquis' (1968) model and Slaughter's (2000) model. This shows the stages of the procurement process and the activities that occur at each stage. However, to correlate these stages with the occurrence of constraints a risk assessment technique is required. Such a technique is Failure Mode and Effect Analysis (FMEA).

3.2 FAILURE MODE AND EFFECT ANALYSIS (FMEA)

FMEA is a charting technique developed for use in the military and aerospace industry (US Military STD, 1980). There has been very limited application of the technique within the construction industry (Andery P *et al.,* , 1998; Nielsen, 2002). Unlike many risk assessments methodologies FMEA is primarily a tool to assess design risk and particularly design related to products and processes. FMEA recognises and evaluates potential failure points (constraints) in a product or process and their subsequent effect. Ranked conclusions identify those constraints, which require greater preventative action. The benefit of this technique is that it can be applied during the design process (Functional FMEA) to enable the designer to manage the potential risk of future failures as well as in retrospect (Hardware FMEA) to ascertain why a failure occurred (Manchester University, 1990). Evaluation of the results can be readily obtained through simple calculation procedures. This is a key objective in the use of FMEA. Ease of use of the model means that Client and other industry stakeholders can use it. The conclusions of FMEA are correlated with the Concept Model to ascertain the stages at which the constraints had most perceptible effect. After numerous case study analyses this will constitute the Detailed Model.

3.3 CASE STUDY ASSIMILATION

There are four case study groups for the purposes of this research. Case Study Group (A) (Table 01) and Case Study Group (B) represent retrospective construction projects drawn from architectural practices in the UK. They are randomly selected according to the evidence of an innovation having successfully sustained the procurement process i.e.: it is identified within the completed building. They are product innovations and are a combination of adopted and practitioner-generated technologies derived from various procurement types.

Innovation		**Innovation Type**	**Procurement Type**
(1)	Specialist glazing system	Product	Traditional
(2)	Circular Lintel	Product	Traditional
(3)	Modular Construction	Product	Prime Contracting
(4)	Composite wall panel	Product	Performance Related partnering (PRP)
(5)	Passive heating system	Product	Design and Build

Table 01 **Case Study Group (A)**

Analysis of the resulting data will constitute the Test Model which will be fed into Case Study Group C; a current live construction project. A process of Action Research will be carried out within the live project and the result is a generic Innovation Management Model (IMM). This represents the culmination of the overall research. It is conjectured that the final model could be flexible for adaptation to other procurement types and that with additional resources further research could be carried out to specialise the IMM for one specific type of procurement (Figure 05).

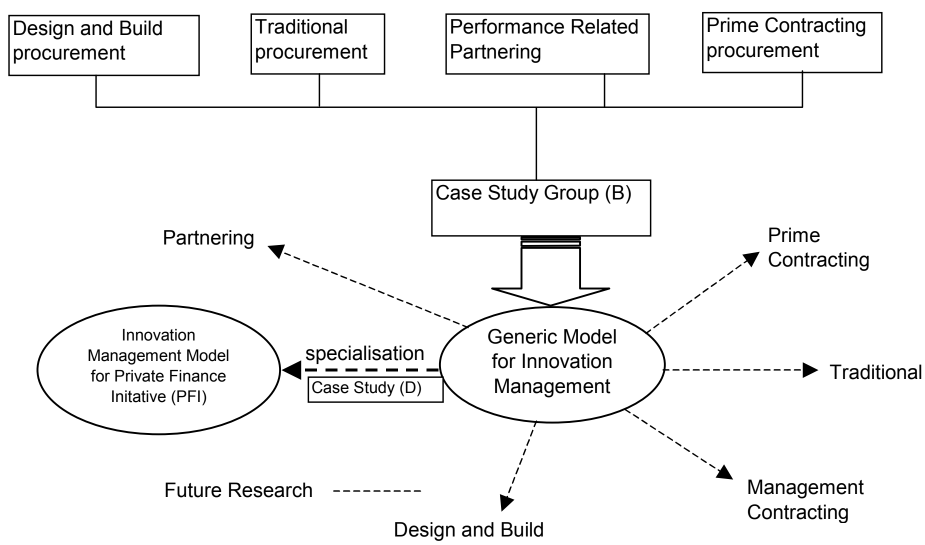

Fig.05 Future formulation and specialisation of the Innovation Management Model

3.4 CASE STUDY ANALYSIS

Each case study is exposed to a process of filtering, tracking and reporting whereby information is gathered on the 'passage' of the innovation during its lifecycle in the procurement process. The process of *filtering* identifies the original technology within the final design of the building. This indicates that the innovation had sustained the procurement process. A process of *tracking* then ascertains the 'passage' of the innovation through the procurement process. It's primary objective is to identify the impact of constraints which were present during the procurement process. For the purposes of the Pilot Study this stage involves a structured interview and questionnaire with the architect. The results of the filtering and tracking processes are *reported*.

4.0 PILOT STUDY

The Pilot Study affords the opportunity to test the literature-based research already undertaken and inform the ongoing research. The Pilot Study selected is one, which has successfully been incorporated into a building having sustained a Traditional form of procurement ('separated' system). It involves the use of Okacolor glazed walling system, a double leafed external glazing system that has unique light diffusion and insulation properties as well as exhibiting aesthetic, multi-tonal colour changes (Fig.06). It was adapted for use in a swimming pool in Belfast primarily for its ability to diffuse sunlight reflected off the pool water. This use of Okacolor is its first ever use in the UK and globally, the first time the product has been used in a swimming pool environment, unique with its variable humidity, temperature changes and air movement requirements. Such technical constraints all imposed a heightened degree of risk to the design and the client's decision to use Okacolor. Another factor, which carried substantiative risk, was that of maintenance and vandalism. Okacolor was used in a socially disadvantaged area with the potential for vandalism and community rejection. Such fears did not materialise and the building is highly regarded by its users. In order to commence the analysis of the Pilot Study it is necessary to undertake a number of literature-based studies to inform the analysis. These are (1) the formulation of a generic procurement process and (2) the development of the Concept Model.

Fig.06 Okacolor used at the Falls Road Swimming Pool, Belfast

4.1 FORMULATION OF A GENERIC PROCUREMENT PROCESS

The Pilot Study is selected from Case Study Group (A). Due to the varied procurement systems from the case studies result it was considered necessary to formulate a generic procurement against which to assess all the case studies. The innovations in this research are consultant-led and are derived from the architectural design of a construction project. Therefore, the generic procurement process devised must reflect the stages critical in appraisal of a design-generated innovation. The generic process was formulated following a comprehensive review of the literature. The resultant seven generic procurement stages, for a building design innovation, are: (I) development of brief, (II) formulation of detailed design, (III) resolution of detailed design, (IV) production information, (V) mobilisation for site works, (VII) implementation of building design and (VIII) completed building.

4.2 FORMULATION OF THE CONCEPT MODEL

The generic procurement process is the basis for the Concept Model. The Concept Model presents a functional correlation between three literature-based models namely, the generic procurement process, Marquis' (1968) model of the process of innovation and Slaughter's (2000) model of the implementation of innovation into the construction project. The Concept Model shows the stages of the procurement process and its activities correlated with the process and management of an innovation (Figure 07).

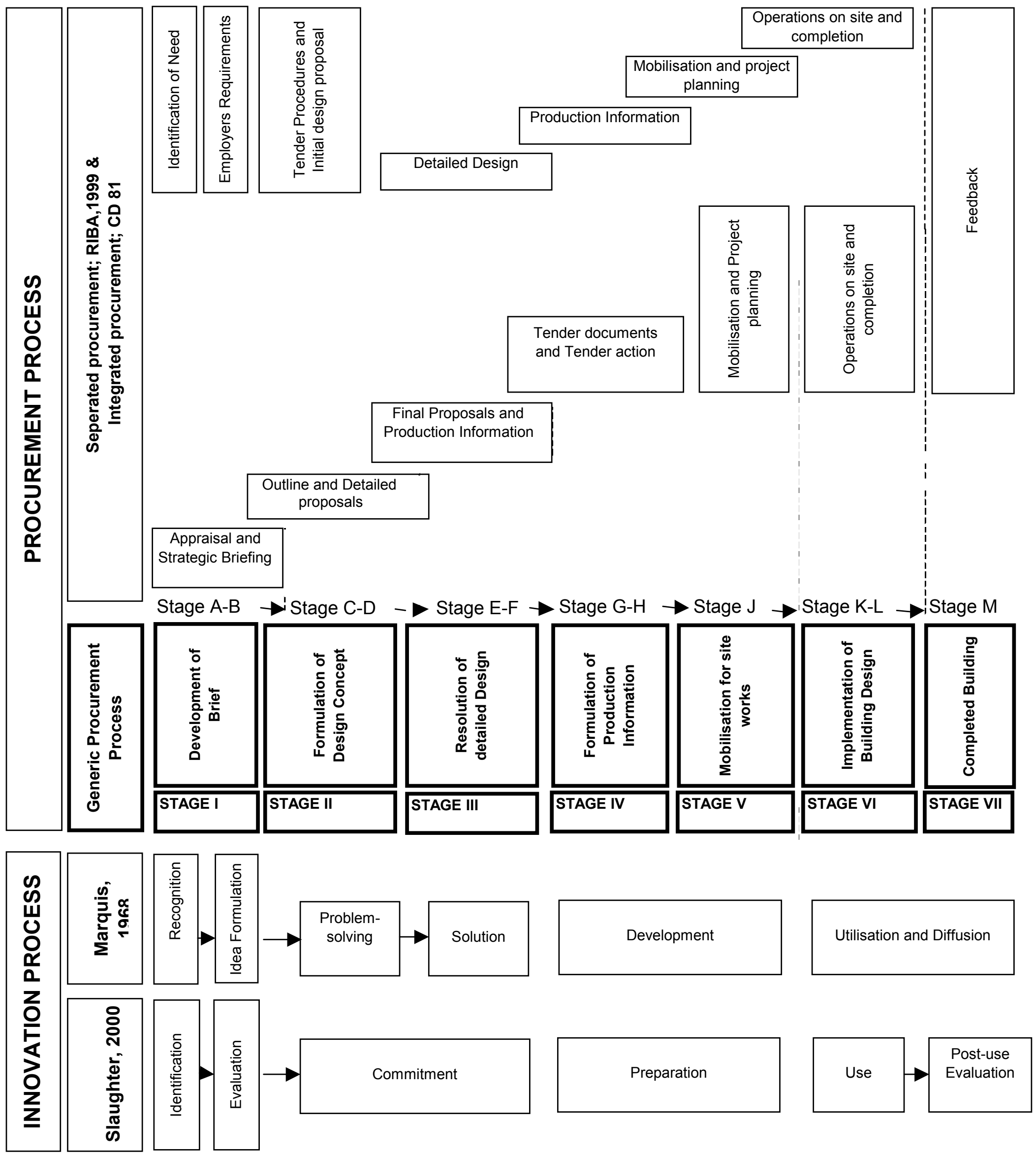

Fig.07 Concept Model

4.3 APPLICATION OF FMEA

In order to correlate the Concept Model with the Pilot Study material an FMEA was applied. In this instance a Hardware FMEA is applied. The assessment of Okalcolor is carried out at Stage VII of the generic procurement process is shown in Table 02. At this stage the building is complete and the innovation has been successfully incorporated into the building. The chart gives a brief description of the innovation under analysis (1) and lists the main functions of the innovation (2). In column (3) each potential failure of the innovation is listed. Since the FMEA is carried out in retrospect the potential failures have not yet occurred. If one of these failures did occur the cause of the failure could be tracked using this method. Column (4) lists the causes for failure. It is these causes or 'constraints' on the process that are collated against the generic stages of procurement (11) in which they occurred by calculation of the Risk priority

Number (RPN) (Occurrence (O) x Severity (S) x Detection (D). The aspect, which is not addressed within the analysis, is that of Client rejection of the innovation. This can occur at any stage in the procurement process. The Client, as key stakeholder, champion and paymaster of the project has the ultimate role in the sustainability of the innovation. Therefore, whilst this research will devise a management model for innovation it is the Client who must ultimately be convinced of the need and validity of the innovation at the concept design. In the case of Okacolor the architect cited that it was the Client who, “was at the heart of the approvals process,” and who “fully supported and advanced the adoption of the innovation”. The conclusions of this analysis are correlated with the Concept Model to ascertain the procurement stages at which constraints had the most perceptible effect. From this the passage of the innovation was traced onto a graph (Fig.08). This graph plots the constraint ‘value’, against the generic procurement process.

Item (1)	Function (2)	Failure Mode (3)	Cause (4)	Effects (5)	(O) (6)	(S) (7)	(D) (8)	(RPN) (9)	Action (10)	Procurement Stage (11)	KEY
Okacolor is a coloured light diffusing and insulating glass. It produces even room illumination without hard shadows and, used as wall cladding, the units minimise heat loss, solar heat gain and the effects of UV radiation.	Provide an effective building envelope	Water ingress to the building	Poor detailing of junctions at design stage	Potential for internal damp and associated safety issues	5	8	7	280	Most urgent preventative action required	IV	(1) Innovation under analysis
				Reissue of production drawings	7	3	3	63			(2) Contribution of the innovation
			Poor selection of subcontractor	Poor standard of detailing	4	9	3	108		V	(3) Potential failures
				Potential for poor future maintenance							(4) Cause for failure
		Failure of glazing unit	Incorrect specification	Delay to enable re-specification	4	4	3	48		III	(5) The effects of the failure
			Faulty glazing unit	Delay to allow for replacement	4	4	9	144		VI	(6) The likelihood of Occurrence of each potential failure on a 1-10 scale
	Provide a strong aesthetic statement	Non-aligned fenestration	Non-coordinated drawings	Unbalanced façade appearance	5	3	7	105		IV	(7) Ranked Severity on a 1-10 scale
		Colour selection	Poor design selection by design team	Poor overall building appearance	2	2	2	8	Least urgent but necessary action required	II	(8) Ability of the current design controls to Detect a potential cause of failure on a 1-10 scale
		Vandalism	Poor social acceptance by local community	High maintenance costs and closure delays	5	6	9	270		VII	(9) The Risk Priority Number (RPN) for the item
	Provide high Insulation and light diffusion qualities	Internal temperature rises	Poor design and coordination with mechanical and ventilation works	Unpleasant internal building environment for users	6	8	3	144		III	(10) Action to be taken and ranked priority
		Poor internal visibility for users	Poor design of glazed area with surface water area	Health and safety risks for users	5	8	3	120		III	(11) Stage in the generic procurement process at which the constraint (3) occurred

Table 02 FMEA Assessment of Okalux

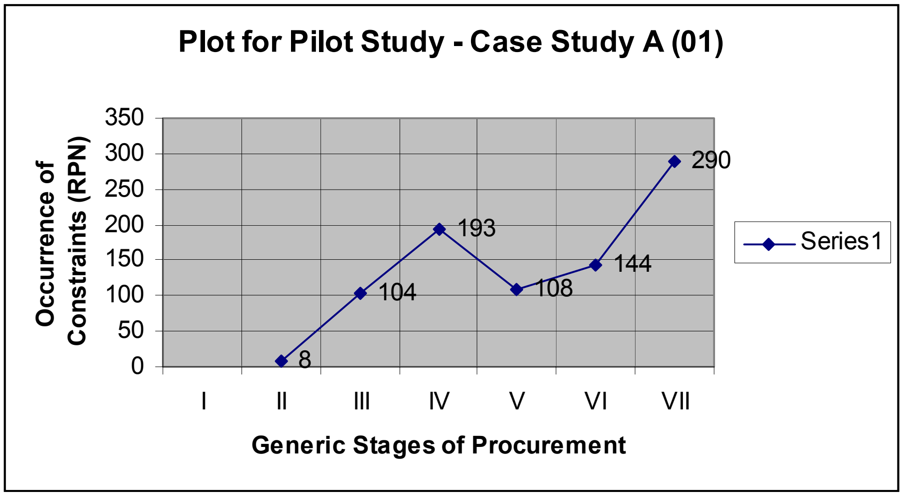

Fig.08 The occurrence of constraints on the implementation of Okalux, during the procurement process

5.0 CONCLUSIONS

The objective of this paper was to outline a methodology to investigate the impact of construction procurement stages on the delivery of consultant-led, project-based building design innovation. The methodology presented is one that combines literature-based study with case study analysis. The overall research from which the paper is drawn seeks to develop a management model for sustaining innovation in the construction procurement process. It is considered that the management of an innovation at particular stages of the procurement process may have a determinant bearing on the ability of an innovation to sustain the lifetime of a project. This has implications for innovation uptake by consultants and Clients.

In this paper a literature-based Concept Model has been formulated into which a Pilot Study has been subject to analysis using the risk assessment tool FMEA. The subsequent analysis identified those factors, which potentially heightened risk for the delivery of an innovation at the various stages of the procurement process. The graph (Fig.08) indicates that the construction stage of the procurement process had a higher level of constraint activity, with the potential to adversely affect the sustainability of the innovation. However upon closer analysis it is evident that such constraints were primarily design-related issues. This would imply that if these constraints had been managed at an earlier stage in the procurement process i.e.: concept or detailed design stage, they would not be constraining factors in the construction stage. Such conjectures pose the question; to what extent could more focused management of the innovation during the design stage have averted the level of constraint impacting on the innovation during the construction stage? Such conjectures will be fed into the ongoing research.

The Pilot Study forms part of a wider programme of case study analysis incorporating both retrospective as well as live construction projects. The resultant model derived from this research will be a generic Innovation Management Model (IMM). It is proposed that industry professionals and clients, as part of value engineering procedures, could easily use this resultant model. Furthermore, that with further research the Model could be specifically adapted for use by one procurement type.

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PROCUREMENT AND RISK MANAGEMENT

Case Study

BRISBANE CITY COUNCIL @ BRISBANE SQUARE "CLIENT INITIATED BUILDING"

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ABSTRACT

How did a client organisation, such as the Brisbane City Council, drive the agenda for a new privately owned 5 Green Star Commercial Building in the Brisbane CBD – Brisbane Square?

After an unsuccessful attempt to sell its current central administration building in 1998/99, the Brisbane City Council set about a detailed planning process in order to determine the most appropriate accommodation solution to meet its future needs. Being the largest Local Government Authority in Australasia and a single city administration, it was considered necessary that its future central administrative functions should be accommodated in a significant CBD facility.

The Council was also driven by the need to position itself consistent with its Vision 2010 for the future of the City. An important part of its accommodation planning was to 'lead by example' and to provide facilities that would enable its 'Vision' for Brisbane City to be readily achieved.

Other key benefits focusing on Council's change management associated with this project are primarily:

1. Successful Relocation (2000 staff over 10 weeks)
   This represented an opportunity to standardise corporate accommodation for over 80% of Council's commercial office space.
2. Reduced occupancy costs
   When compared to the current Council owned CBD building.
3. Improved staff satisfaction and productivity
   Associated with significantly improved work environment, better functionality and more efficient interior design.
4. Alignment of policies to new work practices.
   Leading to improved productivity and efficient use of the work environment.
5. Showcase change agenda with sustainable outcomes.
   Brisbane City Council leading by example and setting the standard for development of large commercial CBD properties with "best practice" ESD outcomes.

Keywords: Corporate Vision, Planning, Leadership, Commitment, Change

1. PREAMBLE

Often a simple situation or particular circumstance can trigger a much more deliberate and thorough planning process. Such was the case at Brisbane City Council with regards to undertaking strategic accommodation planning for Council's Corporate Real Estate (CRE) portfolio. It all started with the failed attempt to sell the Council's central administrative building (Brisbane Administration Centre or BAC) in the CBD in 1998/99.

This disposal process did not result in a completed sale and as such, Council took the decision to retain ownership and risk, at least for the short-term, whilst it developed a more comprehensive approach to its long-term accommodation needs.

This prompted a comprehensive planning process, involving both internal and external resources, in order to determine fully costed options for the Council's future commercial and industrial accommodation requirements.

At or about the same time as this comprehensive CRE analysis was being undertaken, the Council also developed its Strategic Vision (Vision 2010) for the future of the City of Brisbane. Obviously, this 'Vision' also applied to Council itself, indeed the organisation was very enthusiastic to set an example to the rest of the community for the various themes inherent in the Vision.

A public Expression of Interest (EOI) process resulted in a successful submission by Suncorp for a new and innovative commercial building on the former Trittons Site, adjacent to the Brisbane River in the heart of the CBD. Council chose this building for a 20-year lease commitment. At the same time deciding to sell its current CBD building as a vacant possession sale, thereby committing itself to a long-term leasehold arrangement. This commitment, and the desire to show leadership in CBD development, particularly in the area of environmental sustainability, has resulted in both Council and Suncorp investing an additional $5Million to achieve a 5 Green Star Rating for Brisbane Square as part of the Green Building Council's ESD Rating Scheme.

The building is due for completion in mid-2006. It will be the largest privately owned 5 Green Star rated commercial building in Australia. Additionally, the relocation in mid-2006 involves almost 4,000 staff from Council and Suncorp. It is architecturally and technically a very innovative development. However, Brisbane City Council and its needs for the future of the City of Brisbane have driven much of this innovation.

2. CORPORATE VISION

Brisbane City Council's Vision 2010 is a major factor in aligning organisational direction, corporate objectives and strategic planning to ensure all are collaboratively working towards the achievement of the eight inherent themes. These themes are:

a. Accessible City;
b. Active and Healthy City;
c. City Designed for Subtropical Living;
d. Creative City;
e. Clean and Green City;
f. Inclusive City;
g. Smart and Prosperous City; and
h. Regional and World City.

The themes of 'Clean and Green' and 'Accessible City' are major contributors towards design standards aimed at achieving ecologically sustainable development and accessible facilities design. Some of the key design elements, inherently captured by these themes are as follows:

Clean and Green	Accessible City
• Water re-use and energy efficiency initiatives in households, industry and community facilities	• New Busway corridors • More gas Buses for the City – 120
• Clean air – implementing an Air Quality Strategy	• Expand community-based transport initiatives
• Reducing energy use	• Pedestrian and bike friendly city
• Waste as a resource for re-use	• Urban Greenways network – linking communities.

This Vision 2010 has been a major contributor towards planning considerations across the organization, but importantly it has also influenced Council Strategic Accommodation planning and considerations on design and future development.

This situation ultimately led to the decision for Council to invest in Brisbane Square in the manner it did, and to ultimately be instrumental in the creation of an iconic building as an example for commercial development in Brisbane.

3. STRATEGIC ACCOMMODATION PLANNING

As mentioned above, Brisbane City Council commenced strategic accommodation planning for its Corporate Real Estate (CRE) portfolio upon the failed attempt to sell the Brisbane Administration Centre at 69 Ann Street in 1998/99. After initial analysis it was clear that the Council was facing unacceptable capital costs in future years associated with the risk of ownership of a major CBD asset.

This situated prompted a comprehensive review of Council's CRE assets and lead to the public invitation for Expressions of Interest (EOI) for replacement central administrative headquarters in close proximity to City Hall. This resulted in the eventual acceptance of an offer from Suncorp to develop the former 'Trittons Site' for Council's leasehold.

Significantly, part of this process involved the confirmation by the political leadership in the organisation that Brisbane City Council, as a single capital City administration, needed to have a prominence in the Cityscape and business profile in the CBD. This further emphasised the decision that Brisbane Square represented a very good alternative to the current property profile.

Similarly, Council also confirmed that it should retain and develop its strategic landholding on the City Fringe at St Paul's Terrace, Fortitude Valley. This asset and the current market conditions in Brisbane presented an opportunity to develop the site for Council and the wider community without significant capital outlay. This once again presented an opportunity for a public Expression of Interest (EOI) process based upon a sale and leaseback methodology.

However, whilst this and other aspects of the Council's strategic accommodation planning are progressing, let's not loose sight of the "Main Game" at Brisbane Square.

In determining the best outcome for Council in the CBD, there were a number of property options investigated. These options involved both the development and/or refurbishment of our existing facility and the development off site. In summary these options could be best described as:

a. **Option 1** – Status Quo or 'Do Nothing' Option;
b. **Option 2** – Refurbishment and/or extension of the existing BAC Building;
c. **Option 3** – a... Construct additional office tower on site.
   b…Demolish existing BAC Building and build new larger tower on site.
   c…Refurbish and sell existing BAC Building (Value-Added Sale)
d. **Option 4** - Sell existing BAC and City Plaza site (As Is) as a vacant possession sale and lease new premises elsewhere in the CBD,

A comprehensive planning process followed, and ultimately lead to the decision by Council to implement Option 4, thereby moving to new premises. In making this decision, Council was keen to ensure that the following objectives were satisfied as part of the procurement process:

- Facilities that enable Vision 2010 capability – *"a suitable work environment for the future";*
- The ability to control Council's future accommodation risks, costs and location security;
- The ability to minimise the risk and cost of ownership into the future;
- Provide budget certainty in any financial undertaking, seeking best value from any negotiations undertaken;
- Not impact on Council's credit/debt profile *(Standard & Poors Rating of AA+)*
- Maximise the sale revenue from the disposal of the BAC and City Plaza site – achieving a market-based return on investment;
- Site selection that achieves a smooth transition for staff, productivity improvement, positive change environment, etc.

A public Expression of Interest (EOI) process followed for both the sale of the BAC and City Plaza site and the development of replacement facilities for Council's central administrative functions. This resulted in Council receiving 12 separate submissions over 7 discrete sites, all within relatively close proximity to City Hall. The ultimate selection being a 20-year leasehold arrangement, over a portion of a commercial office development at Brisbane Square.

4. LEADERSHIP AND COMMITMENT

A major change initiative of this kind does not happen without strong leadership and commitment by staff. In the case of Brisbane Square successive Lord Mayors have seen the merit in having a more productive workforce and providing excellence in customer service for the people of Brisbane. Likewise, the CEO and her Senior Executive have been instrumental in guiding the Council's process of change and ensuring the Brisbane Square will provide a working environment and customer interface for the future.

Brisbane Square will create the largest public Library and Customer Centre in the Asia-Pacific Region and provide a place of destination and interest in the developing heart of the City. But more significantly, particularly for the future, the development will also contain the following unique characteristics:

- Environment design and sustainable development resulting in a 5 Green Star Rating under the Green Property Council's ESD Rating Scheme and a 4 Star (Plus) Rating under the Australian Building Greenhouse Rating (ABGR) Scheme;
- The new home of the Brisbane Metropolitan Transport Management Centre (BMTMC), which is a joint venture alliance between Brisbane City Council and the Queensland State Government involving Brisbane Transport and the Departments of Main Roads and Transport;
- Combined Staff Gymnasium for both Suncorp and Brisbane City Council staff accommodated at Brisbane Square;
- 2,200 square metres of Civic Square provided to Council as public open space and co-existent with the top end of the Queen Street Mall. It will be an important extension of the public domain;
- Bike storage and change facilities for over 200 bicycles with direct river tunnel access for pedestrians and bike riders (Tenant access only) from the riverbank direct into the Basement level amenities.
- Predominantly, open plan office accommodation including conference and meeting facilities, carers room, prayer room, medical facilities, data centre, etc; and
- Modern and vibrant retail precinct, complimenting existing retail in the heart of the City's CBD.

5. PROJECT AND CHANGE MANAGEMENT

Ultimately, Brisbane Square involves the relocation of over 4,000 staff (2,000 from each of BCC and Suncorp) to the site. The coordinated Project Management and focus on the Change Management agenda has seen this project developing as a model for large-scale change in Australia.

The critical benefits or focus for Council's change management associated with this project are primarily:

- Successful Relocation (2000 staff over 10 weeks)
- Reduced occupancy costs
- Improved staff satisfaction and productivity
- Alignment of policies to new work practices, and
- Showcase change agenda with sustainable outcomes.

Initiatives such as Staff Display Centres, Marketing and Promotion, Relocation Planning, Consultation techniques, etc, are all considered leading edge innovations. All of these innovations have contributed towards what is expected to be a successful change management project outcome.

6. CONCLUSION

Clearly, Brisbane Square has resulted because of Brisbane City Council's planning and initiative. It was such a good concept that the original landowner (Suncorp) also decided to relocate over 2000 staff to the development and lease the remaining commercial office area.

The development is strongly supported by both tenant organisations, based upon their respective corporate visions and the desire and commitment by both Council and Suncorp to create a 'Clean and Green' and 'Accessible' development. This iconic development will assist greatly in instilling the same values in the City of Brisbane's CBD development overall.

There is no doubt that Brisbane Square is a 'Client Initiated' development. But more importantly the 'clients' are determined to ensure its success into the future.

PROCUREMENT AND RISK MANAGEMENT

Case Study

TOWARDS BLUE PROJECT OUTCOMES - THE ROADMAP TO PROJECT EXCELLENCE

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ABSTRACT

In 2000 the Property Council of Australia commissioned the authors to determine why some building and engineering projects performed extraordinarily better than others. Following more than 200 hours of interviews with project team members on 34 projects, it was concluded that 10% of projects perform much better than the rest against 5 criteria of "excellence":

Keys to achieving these results were having:

- A client trained to be a client;
- A project environment conducive to forming trusting relationships and creating wealth, not just financial; and
- A focus on removing the wasted effort, often more than 30% on most projects.

Following this research the authors designed a "roadmap" which allowed project teams to replicate extraordinary project outcomes, by designing project delivery strategies using a maturity model.

The authors have applied the roadmap, through facilitated workshops, to design project delivery strategies and initiate projects. The first of the projects where the roadmap was used is now complete. This paper will report on the success achieved, limitations of the roadmap and future opportunities for continuous improvements to "business as usual" project delivery models:

- Virtual organisations being created of all project team members;
- Design chains involving trade contractors working with design consultants in co-located premises, to produce 'for manufacture' designs;
- Construction chains of several interdependent trade contractors becoming self-managed teams;
- Payments being made weekly for defects free functional output by construction chains;

- Automated payment cycles eliminating paperwork;
- Supply chain management to overcome the fragmented blame culture of the construction industry;
- Process re-engineering to remove wasted effort and substantially increase contractor margins.

Importantly, the case study project was unviable until the approach was applied, removing sufficient wasted effort to both become feasible and improve margins.

Keywords: Project strategic planning, client involvement, project turning points, excellent project drivers, removing wasted effort.

1.0 INTRODUCTION

In 2000 the Property Council of Australia commissioned the authors to determine why some building and engineering projects performed extraordinarily better than others. Following more than 200 hours of interviews with project team members on 34 projects, it was concluded that 10% of projects perform much better than the rest against 5 criteria of “excellence”. The results of the study were published in 2001 in **Projects as Wealth Creators** (Barda and Crow 2001).

The criteria of project excellence adopted were:

- End users being delighted;
- Client having achieved expected returns;
- Supply team members having made or exceeded expected margins;
- Supply team members having enjoyed working together;
- Community standards for safety, design and environmental performance having been achieved.

The study found a clear correlation between the achievement of excellence on a project, and the creation of greater wealth than was expected at its inception. This finding was subsequently validated in a review of 5 projects by the authors, commissioned by the industry superannuation fund C+BUS.

Following this research the authors designed a “roadmap” which allowed project teams to replicate extraordinary project outcomes, by designing project delivery strategies using a maturity model.
The Roadmap provides a means of planning the journey that project team members undertake when they commence a project. The correlation between the level of performance achieved, and wealth creation, is depicted in a distribution curve based on the **Projects as Wealth Creators** study (Figure 1). Colours have been used to reinforce project team members’ identification with a desired, and planned for, level of performance and wealth creation.

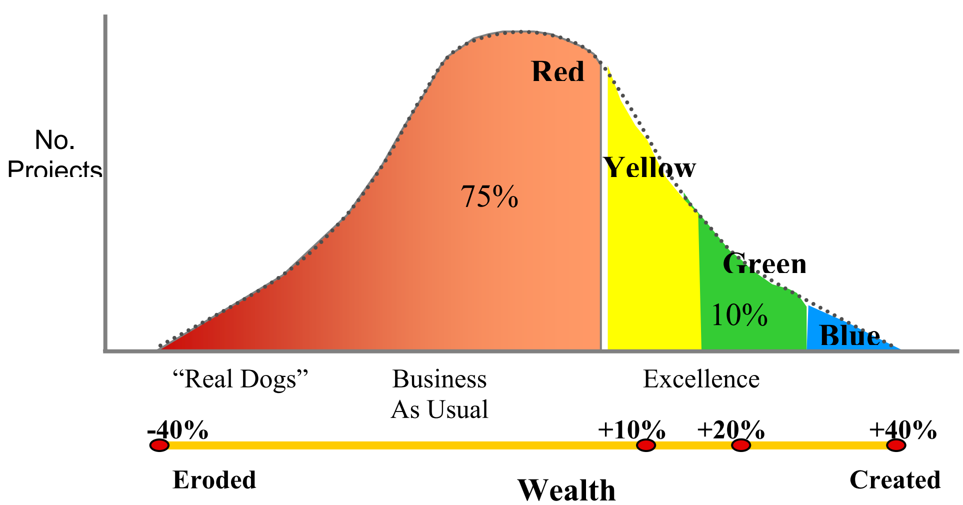


Figure 1 Project Performance Distribution

Projects as Wealth Creators found that 75% of projects (characterised by the authors as ‘business as usual’ and coloured red) underperform their potential for wealth creation, whilst only

10% achieve excellence (coloured green). The virtually unattainable "beyond excellence" is coloured Blue and is based on world's best practice in all industries.

2.0 CASE STUDY PROJECT OUTLINE

Victoria Park is a residential development 5 kilometres south of the Sydney, Australia Central Business District, sponsored by Landcom, the New South Wales' Government's land development agency. Landcom's vision for Victoria Park

> *is that of a vibrant mixed use community with a distinctive and memorable character which is well integrated into the existing fabric of South Sydney. The successful development will act as a catalyst for the transformation of the Green Square Development Area." [Victoria Park Masterplan*]

The case study project known as FORM is of one part of the overall Victoria Park development. It was the fourth consecutive project at Victoria Park undertaken by the Waltcorp Development group. The FORM development involved:

- Land price of A$25 million;
- Land size of 6,000 square metres;
- 221 apartments (1, 2 and 3 bedrooms);
- Total cost of A$130-140 million;
- Construction costs of A$72 million; and
- Construction period of 67.5 weeks, with completion in June 2005.

FORM comprises 4 separate buildings with a total of 221 residential units and 6 retail spaces, a central landscaped courtyard and basement car parking for 300 cars. The individual buildings range in height from 4 storeys to 14 storeys. Bored piles to a depth of 30 metres support the 14 story tower building, and a raft slab supports the 3 low rise buildings.

FORM was developed with the majority of load-bearing and façade structural elements being precast. The finished treatment of the precast is a mixture of painted panels, ribbed profile panels, and a lightweight cladding systems. The remainder of the façade is made up of glass and precast balustrades enclosing apartment balconies. Full height façade glazing has been utilized on all 4 buildings and assists in the provision of "breeze-through" effects to the apartments, enabling outstanding Environmentally Sustainable Development ratings to the project.

3.0 PROJECT ENVIRONMENTS

The premise of this paper is that the project environment will determine whether it is possible for significant improvements to be made in the performance of building and engineering projects.

The Concise Oxford Dictionary defines environment as *"surrounding objectives, region or conditions, especially circumstances of life, person or society*".

In the context of project strategies, the authors consider project environment as that which establishes the ambience, value system, relationship protocols and behavioural standards within which project team members will be expected to operate. Ward (1997) defines it as the aggregate of all cultural, political, geographical, physical and technical conditions surrounding and influencing a project. This is supported by Liu (1999) who suggests that the success of a project is often dependent on the right policy environment and the changes in policy forced on a project by an unfavourable external environment.

A broad review of the literature shows a trend that research on procurement systems is moving from a technical to a more behavioural approach impacted by cultures. Kilmann et al. (1985) argues that culture is a collective disposition to establish the shared philosophies, ideologies, values, assumptions, beliefs, expectations, attitudes and norms that knit a project community together.

McDermott et al. (1997) suggests that this trend may have a strong potential for explaining the differences in performance across projects. Other researchers suggest that culture has become an important issue in analysing procurement systems (Rawlinson and Root 1997, Rooke and Seymore 1996). In this context, culture determines what behaviour is acceptable and expected from members (Gray 2001). The explanation seems to be that project pre-history and prior working relationships have a most significant impact on project culture. McDermott et al. (1997) conclude that development of a positive project culture, even before a contract is let, is the best means of ensuring a successful project, provided that a fair price is paid for a good job. The authors support this contention, having found that an inadequate budget has generally resulted in confrontation and caused teams to be unco-operative and defensive, while draining away energy from creativity, the major source of wealth creation.

Gray (2001) asserts that the relationship between culture and climate/environment is complex, but that climate can be thought of as the sum of the effects of culture as perceived by an individual. Gray (2001) also argues that a low-threat, secure and stable project environment in which individual contribution is maximised within a distinctive team culture, offers the optimum opportunity for successful project outcomes. He states that a supportive organisational environment is a key factor in successful project outcomes while organisational change and environmental uncertainty are negatively associated with successful project outcomes.

In summary, the literature is indicating a high level of significance and impact of the project environment on a project's outcome.

4.0 CREATING PROJECT ENVIRONMENTS

The ***Projects as Wealth Creators*** study (Barda and Crow 2001) demonstrated that trust, values, equity and risk allocation are key determinants of the project environment created by the client, which is the first Turning Point of a project journey. Once that project environment has been established it is vital that as team members are selected, varying trust, inconsistent values and differing approaches to equity and risk management should be avoided from the outset to ensure no disputation.

To optimise asset service delivery strategies, and team selection, all members of the existing client team must be able to articulate a clear and consistent description of the attributes of the project environment, i.e. the values and approaches which will drive them, and the project.

A Roadmap to Project Excellence (Barda and Crow 2004) has been designed for use by multi-disciplinary teams in a workshop to facilitate the creation of a project environment conducive to outstanding performance.

Two examples of the 32 choices confronting project teams when using the Roadmap are shown (Figure 2).

The roadmap provides a detailed framework against which:

- attitudes, values and approaches of potential project team members can be assessed,
- the extent of alignment (or misalignment) with client team members' attitudes, values and approaches can be tested, and
- the required project environment can be created.

The real-world nature of crossroad decisions enhances the relevance of the workshop, enhancing the 'stickiness' of the decisions made and relationships forged during the workshop.

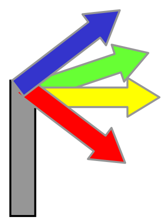
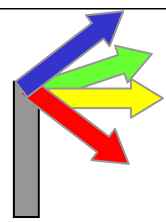
CROSSROADS		ALTERNATIVE DECISIONS
Client risk tolerance		Risk management shared by all team members regardless of contracted responsibility.
		Risk allocated to supplier only if able to control it. Formal risk management workshop held.
		Price negotiations consider risk allocation responsibility. Risks are identified.
		All risks are contracted out (risk averse).
Project director brief		Inspire visionary achievements
		Provide equitable leadership
		Contract limits relationship development.
		Provide inequitable leadership

Figure 2 Roadmap Crossroads to Excellence

5.0 ORGANISATIONAL FRAMEWORK

5.1 STRUCTURE

The organisation structure for the FORM project was prepared so as to achieve enhanced project team relationships, the key to continuously improving towards an excellent project outcome.

The team selected for the Victoria Park projects had the same members as the traditional 'Business as Usual' (BAU) projects. However, the project was structured differently to BAU to enable more constructive comment and faster resolution of design details.

Team members were treated as business partners and included the developer, builder, architect, engineers (structural, mechanical, electrical, hydraulic, acoustic, traffic, geotechnical and environmental) and supply trades (precast, plumbing, electrical, joinery, glazing, mechanical, post tensioning).

The development organisation structure diagram is as figure 3.

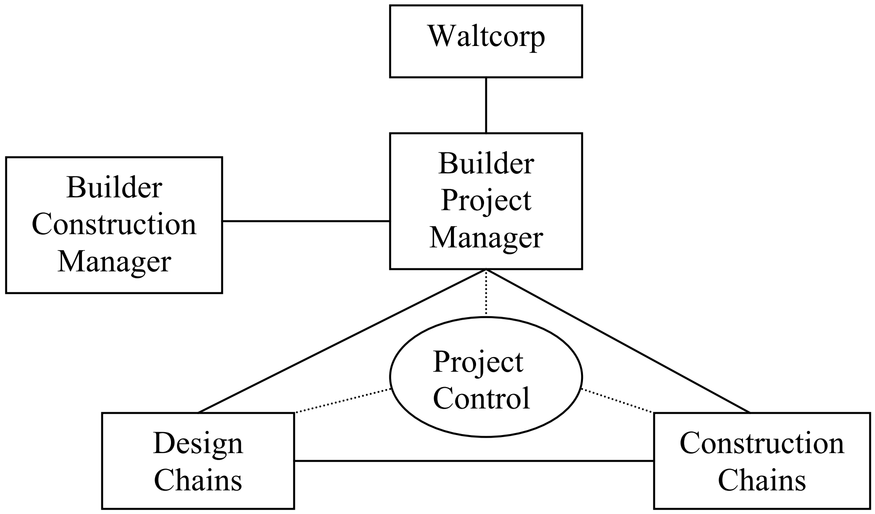


Figure 3 Development Organisation Structure

This structure was designed to reduce conflict and improve information flow.

5.2 VIRTUAL ORGANISATION

The team operated as a virtual organisation for the project, co-located on site to allow their traditional technical skills to be more effectively utilised.

Key elements of the virtual organisation were:

- A single team focussed on a common set of goals and objectives delivering benefit for all concerned.
- A seamless team, which it appears to operate as if it were a company in its own right.
- A "virtual" company, with no apparent boundaries, in which all the members had the same opportunity to contribute and all the skills and capabilities on offer can be utilised to maximum effect.
- Design responsibilities allocated to the "best person for the job", rather than just by traditional roles.

The virtual company removes the barriers between design and implementation. Enabling all parties to be involved in discussion on the principles allowed high quality decisions to be made on the basis of all the implications right throughout the lifetime of the facility being developed.

5.3 ROLES, RESPONSIBILITY AND ORGANISATION

With the development of the refined process of design and documentation, there was a declassification of roles. Traditionally physical barriers in the form of separate offices contribute to a divided approach to building design and documentation. The collocated development design office initiative broke down those barriers and blurred the roles of the people involved in the process (Figure 4).

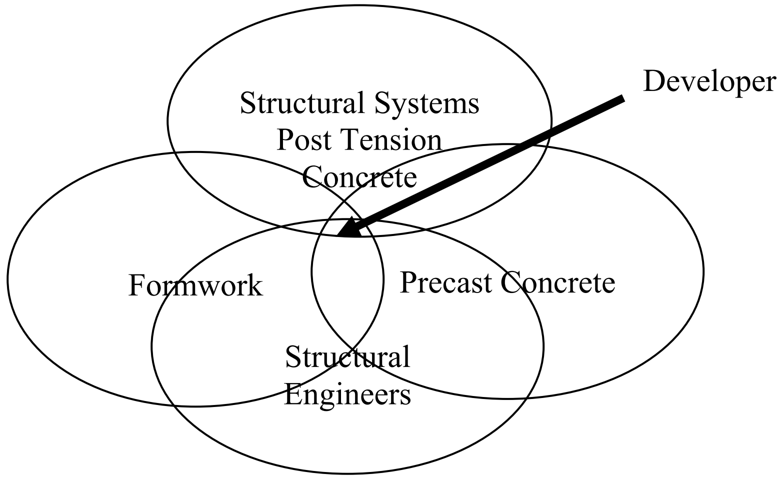


Figure 4 Example of Blurred Barriers

5.4 DESIGN AND CONSTRUCTION CHAINS

The objectives of the Design and Construction Chains were to research, develop and implement design development, documentation and site installation processes so that:

- Wasted effort in the design and construction process could be minimised;
- Defects arising from design decisions and handover of work between trades could be eliminated;
- Margins and job satisfaction could be increased.

These trades, treated as business partners, were involved in concept design and design development, including both formal and informal value management. The organisation structure on FORM was structured around design and construction chains (Figure 5).

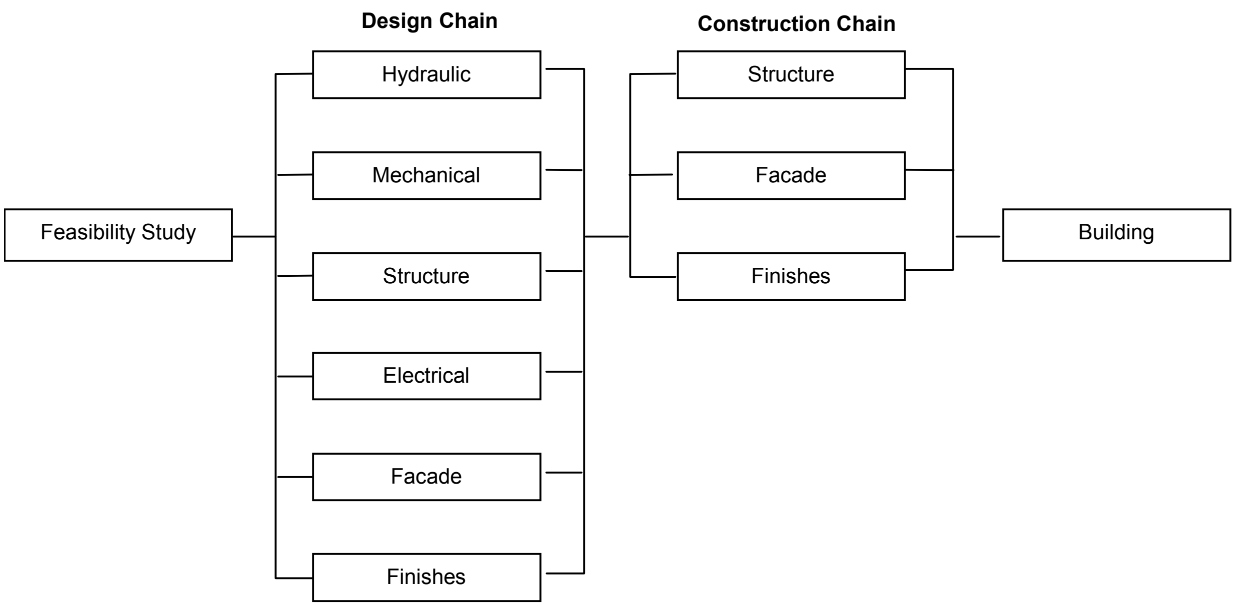


Figure 5 Design and Construction Chains

Benefits were continuously monitored and included:

- Better communication;
- Reduced inquiry and response time;
- Greater knowledge of associated trades;
- Greater focus on quality;
- Less aborted work;
- Greater job satisfaction;
- Increased profits.

5.5 DESIGN CHAIN PROCESS

Design chains were given a brief to work as a virtual organisation, co-located on site to simultaneously carry out design development and manufacture detailing whilst ensuring safety was designed in, buildability is achieved, material handling and commissioning is efficient, all within effective work packaging (Figure 6).

Design chains are that part of a project team which is focussed on designing. It is created when organisations, which repeatedly collaborate in project teams, coordinate their roles to develop project design information for their mutual benefit (Austin et al 2001).

Design, which exists as separate processes carried out by different organisations, can be managed beneficially as a chain across organisational boundaries. In this regard, design activities encompass more than just consultant design, and include buildability, procurement packaging, manufacture detailing, work place safety, prototyping with trades and commissioning.

In summary design chains:

- allocate design processes on the basis of an organisation's technical competency;
- ensure that organisations belonging to design chains have the ability to work together;
- align organisations to improve their combined effectiveness and ensure that processes are not duplicated or missing within the chain (ie remove wasted effort which erodes margins);
- are self-managed teams with the leader being the most capable to lead and motivate creativity and continuous improvement (not necessarily the architect or engineer).

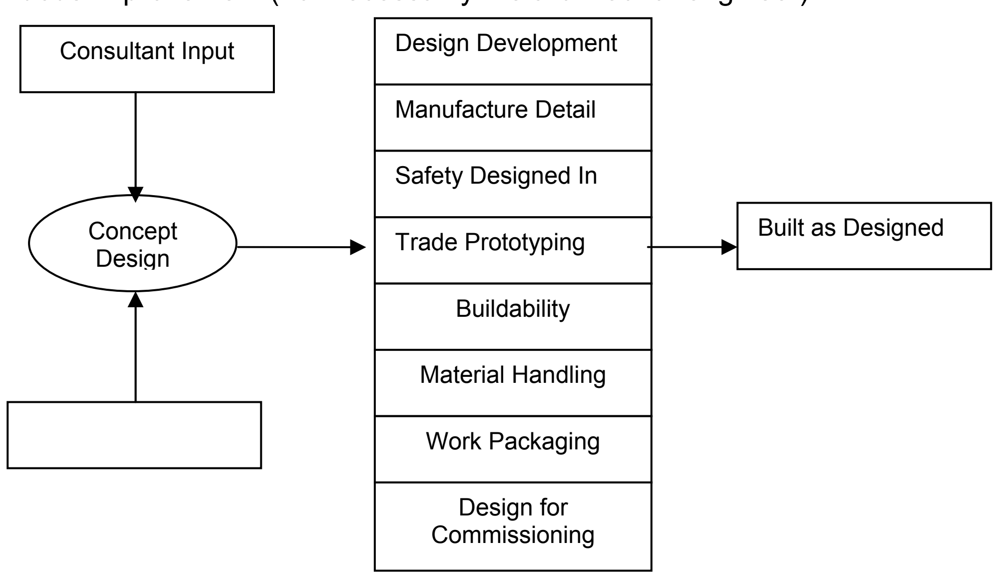


Figure 6 Design Chain Brief

The close working relationship developed allowed key architectural features to be enhanced while excess was trimmed from the project. With clear documentation, construction trade packages were let early gaining maximum benefits in price and timing for sub-contractors and the developer. The clear documentation path also minimized wasted effort for the consultant team.

5.6 CONSTRUCTION CHAINS

Construction Chains are the link between the Design Chains and the finished building. They are a team comprising representatives of associated trades and consultants that are responsible for design implementation and detailing of different components within the project. They are responsible for developing work practices and detailing efficiencies during construction and handover from trade to trade.

The Project Team met with the managing directors of each trade contractor, introduced the concepts, discussed and agreed the implementation to ensure productivity and cohesiveness on site were maximised. In addition, Construction chain workshops were held to introduce the Supervisors to the concepts of "Project Blue".

Construction chains require:

1. The right attitude of both the builder and trade supervisors to assist each other in achieving common goals.
2. An understanding of relationships and teamwork - trades assist each other and do not let each other down.
3. The construction chain consisting of the builder's foremen, site engineers and trade supervisors agree and prepare rolling two weekly programs to achieve required completion dates. These are presented at each weekly construction chain meeting.
4. construction chain members achieving their committed dates.
5. Full time Subcontractor supervision.
6. The builder facilitating construction chain meetings, and working to ensure that all trades actively contribute and are committed to the process.

6.0 BENCHMARKS

The Project's overall performance was benchmarked against five criteria:

- Roadmap to Project Excellence (Barda and Crow 2004)
- Construction cost
- Labour productivity
- Safety
- Quality control.

6.1 ROADMAP TO PROJECT EXCELLENCE

6.1.1 Project Roadmap Concept

The concept of a roadmap being the framework of strategies for achieving outstanding project outcomes, resulted from research for Construction Queensland (Barda and Crow 2001a) and Property Council of Australia (Barda and Crow 2001). The concept for this maturity model was created through a number of focus groups that concluded that it should:

- be behaviour focused but recognise that techniques were an important enabler in achieving excellence in outcomes
- be focused on behaviours that produced trusting relationships
- follow the normal phases of project development (i.e. strategic, initiation, implementation, in-use)
- use a consistent analogy with road journeys so project team members could easily relate to the concept (e.g. by using terms such as crossroads, signposts, roadblocks, bottlenecks and drivers). This clear analogy could then assist in motivating a commitment from team members.

The roadmap maturity model suggested that the various maturity levels could be seen as different pathways or roads to achieve a project's mission of creating wealth by satisfying end-user needs.

6.1.2 Performance Assessments

In April 2003 members of the FORM project team participated in a strategic planning workshop. At that time they were engaged in constructing the preceding Victoria Park block known as ESP, and designing FORM. They made assessments of:

- their current performance on ESP against the Roadmap to Project Excellence, and
- their targetted performance to achieve an outstanding (Blue) project outcome on FORM.

In July 2003 an independent assessment of the work being done on design of FORM was undertaken. Figure 7 shows these 3 performance assessments.

The independent assessment indicated that project performance had moved in the 3 months since April 2003, from Red (Business as Usual) to Yellow/Green (Towards Excellence). The main reason for this improvement was the focus on removal of a number of roadblocks identified during the April 2003 strategic planning workshop.

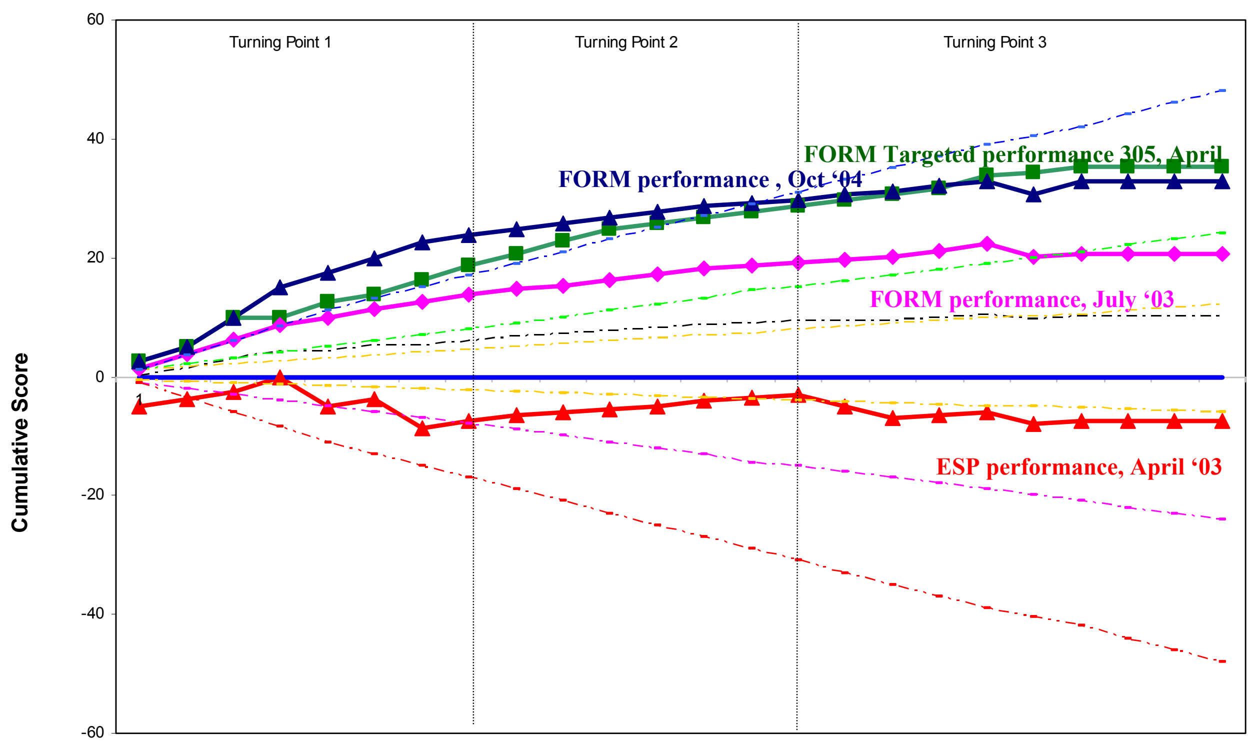


Figure 7 Victoria Park Performance Assessments

In October 2004 a further independent assessment of project team performance was undertaken with the completion of the structure of FORM. It was assessed that FORM was achieving a green excellence status to date, or a 1 in 10 outcome. This assessment was maintained until project completion in June 2005.

6.2 CONSTRUCTION COST

The construction contract was exclusively negotiated on FORM with the business partner trade contractors that had performed well as a supply chain on the previous, ESP, project. Trade prices on ESP were used as the benchmark for negotiations.

As the project was not competitively tendered, to meet a requirement for project finance an independent quantity surveyor priced the project relative to other residential projects of similar size, complexity and quality.

The quantity surveyor concluded that the contract price and margin adopted by the developer was fair and reasonable relative to the year 2003 markets and based on business as usual practices. Thus it was a good benchmark from which to measure continuous improvement.

6.3 LABOUR PRODUCTIVITY

A further benchmark used was the bespoke trade costs (eg structure, precast, electrical, plumbing) which accounted for 50% of total cost and represent the greatest construction cost risk from design, manufacturing and installation. This risk is due to the elements being specifically designed for the project (i.e. not off the shelf manufacturing) and has been found by the authors to be a significant source of wasted effort.

The bespoke trade prices and thus the labour man hours were similar to the quantity surveyor's industry benchmarks and thus based on business as usual practices.

The four nominated bespoke trades advised that productivity was significantly improved on the project with labour man hours being reduced by 10-20 %. They also noted that should the same team have continued on another project, the trusting relationships, which had been forged, would exist from the beginning, resulting in even further improvements.

6.4 SAFETY

A concern commonly voiced in the construction industry is that many small to medium sized contractors are not accurately reporting lost time injuries (LTI's), and that industry average performance is accordingly a misleading benchmark. The FORM project adopted the LTI average based on insurance claims reported to Workcover, the New South Government regulatory authority. A total of 12 LTI's were recorded on Form, compared to 45 on the earlier ESP project.

This analysis shows that the safety record was exceptional by industry standards as further evidenced by the adoption by the workforce of compulsory safety glasses for all personnel (as with hard hats, safety boots and vests) which was a first for a building project in Sydney.

Thus there were no apparent unsafe practices as a result of more efficient work practices and reduced man hours of key trades. The team concluded that the project environment drove this safety record.

6.5 QUALITY CONTROL

The builder reported the following defect outcome after handover of 80 units (Table 1).

FORM Project	Major defects (8 man hours)	Minor defects (1 man hour)
ESP project	1/unit	10/unit
FORM actual	zero	3/unit

Table 1 Defects per Unit

It can be concluded that there was no reduction in quality of construction in pursuit of continuous improvement.

7.0 KEY DRIVERS OF SUCCESS

The key drivers of achieving the excellent outcome on the project were:

- obtaining the commitment of the clients project director
- establishing a project environment conducive to removing wasted effort and thus creating wealth for all stakeholders;
- obtaining personal commitments on roles and responsibilities within value-adding design and construction chains;
- establishing a supply chain which had trusting relationships operating within a virtual organisation;
- selecting supply chain members primarily on the basis of the quality of staff being made available for the project.

These were achieved by conducting several workshops with overt agendas focused on business outcomes eg risk management, business planning, value management, but with the covert agenda of building relationships.

7.1 The Approach

Project planning workshops targeted the Turning Points found by the Projects as Wealth Creators study to be present on all excellent projects.

Turning Point 1: established a **Project Environment**

- where mutual trust and good relationships were seen as cornerstones to success.
- conducive to innovation and creativity by removing angst and disputation, to allow wasted effort to be removed and extraordinary value created .
- led by a client representative trained to be a client, and capable of inspiring visionary achievements by the supply chain.
- with key team members of consultants and trade contractors selected as business partners in a supply chain prior to design development with pricing negotiated as a benchmark to previous projects.
- where risks were contracted to those best able to manage them whilst the team were supportive of each other in mitigating risk exposure of the whole team.

- with the project delivery strategy designed to optimise apartment purchasers needs, not just selected to optimise supply chain returns.
- with the supply chain integrated in a virtual organisation co-located on site, sharing information through common IT, and providing team members on a 'best for the job' basis.

Turning Point 2: established **Project Team Relationships** with:

- team members selected on their ability to creatively work together and demonstrate trustworthiness within the project environment.
- relationship building workshops being facilitated to ensure team chemistry existed within a project 'cooperative'. This wasn't contract-legislated partnering so often found on projects. Everyone found enjoyment from 'walking the talk'.
- team members becoming disciples to achieving the environment and not wanting to let anyone down.
- an open organisational structure, breaking down silos within disciplines and between business partners, with mutual respect for knowledge sharing, and value adding. "I'm the designer, you're just a grubby subbie", was banished.
- design chains and construction chains formed to be the basic framework of the project organisation, eliminating bureaucracy and buck passing.
- recognition that team members can bring attitude 'baggage' from previous projects, resulting in trust and relationships being destroyed before people even meet. This was addressed by business partner owners committed to achieving the environment and a new approach to project induction covering not just safety but also relationships. Further workshops were used to "induct" trade contractor site leaders into forming cohesive self respecting teams.

- Turning Point 3: prepared a **Project Business Plan**, including the tactics required to achieve the project vision and strategies to be documented. This plan was instrumental in achieving a continuous improvement culture over the Victoria Park projects.

7.2 THE RESULTS

The project team and their relationships were severely tested prior to receiving the DA as the local authority decided that previously approved development plot ratios had to be changed. Under normal circumstances this would have made the project unfeasible. But because of the robust team relationships and the virtual organisation approach to design, the 20% wasted effort that had been designed out by the designers and manufacturers still allowed the project to proceed.

8. QUOTABLE QUOTES

Quotable quotes have been found to provide an accurate measure or flavor of the project environment that underpins performance.

"There was a very trusting relationship between us and them. 50% of our company supervisors couldn't handle such a relationship as they haven't experienced it." Working with the architect and consultants was awesome."

"Main benefit of construction chains workshops was reinforcing that they wanted people to work together."

"It was a very pleasant working environment stressed by changes but not by screaming and shouting."

"Project environment is 80% of the challenge to get the attitude right."

"Grubby subbie syndrome has been replaced with consultation."

"Job was so happy it was boring – I felt like creating a Blue just to have an argument."

"I saw the strategic planning workshop as too highbrow – 'why are we talking about this' – my job is to lay bricks. Now looking back I can see it in perspective."

"Our people tripped over each other to work on FORM."

"There were no egos on this job."

"FORM proved that if you take an extra month up front to think, then you'll save a month at the end."

"It's all too easy, just common sense."

"Project Blue? What's that? Now I know!"

9. CONTINUOUS IMPROVEMENT OPPORTUNITIES

While the project achieved an excellent outcome, the following opportunities were identified for continuous improvement.

Managing consequences of design changes
The considerable changes to the design following the rejection of the DA in November 2003 could have been managed more closely. Trade contractors felt that they were not kept informed of what was happening, and that the builder's behaviour reverted at that time to "business as usual". There did not appear to have been a strategy "owned" by all affected to deal with the range of scenarios which were on the table from November 2003 until the DA was re-submitted.
It was apparent that manufacturing "slots" were lost in the delays to design for precast and windows, and this could have been mitigated through consultation.

Greater communication about the re-design process, and the developer's intentions, would have created even greater savings and efficiencies.

Design chains – trade involvement
Interaction between trade contractors and designers could have been further improved upon, and much more use could have been made of trade contractor design and manufacturing skills. Whilst there was overall satisfaction with and support for design chains, there was agreement that more needed to be done to map the design process and use that mapping as the basis for greater elimination of waste.

Consultant Reimbursement
Traditionally, consultants give away their "smarts" and charge for documentation. With the re-engineered processes and design chains, significant design documentation is merged with shop drawings and completed by trades. Further, trade involvement in design chains raises the level of creativity, and thus involves more consultant "dreaming" and conceptual design, resulting in the potential for more wealth to be created for the developer, builder and trades.

However this results in consultants being paid less for doing a better job. This is further exacerbated by site engineers and administrators only measuring design output by documentation, rather than the wealth created.

Whilst consultants have created the problem with their low fee submissions, and not charging for their "smarts", builders must recognize the dilemma and re-balance the payment equation if they are to create additional wealth from Blue projects.

Wealth Sharing

The Form project environment assisted to make the project flexible and created extraordinary wealth for key trades and the builder

- Trades efficiency improvements increased their margins and reduced the builder preliminaries and defects risk. However further sharing of trade margins gains with joint environment creators (builder and consultants) would be possible if:
    - construction chain workshops preceded price finalization
    - as then a green price could be negotiated
    - for the re-engineered process with the trades 'pocketing' the difference.
- Consultant efficiency and "smarts" drives down capital cost as well as improving everyone's margins except their own. This must be rewarded and their self esteem (a form of wealth) restored if builders are to motivate them to create even further wealth.
- Consultants could also share any unspent client contingencies resulting from their innovation and design efficiencies

Project Blue Attitude

It's been observed that competent and experienced staff are more comfortable with 'Project Blue' concepts, and have more acceptance of the need for change. Inexperienced staff are less comfortable and tend to cover this up with the safety of BAU.

Workshops need to be extended to cover all builder and consultant staff so that a consistent message is heard and understood.

All major trades need to attend the strategic planning workshop to ensure an understanding and commitment. Delayed selection of these trades has a detrimental effect and prevents a Blue outcome. When trades are selected late, their induction must include 'Project Blue', otherwise the 'lowest common denominator' will prevail.

Co-location

This concept was pivotal to success on FORM, however it can still be improved on. All consultants and bespoke trades should have as a condition of their appointment the requirement to be co-located and that a common IT framework will be provided.

Design Chain Process

Significant improvements are still possible from removing wasted effort during design. Design chain processes need to be further re-engineered before starting design, finalizing fees and trade prices with responsibilities allocated on a "best person for the job" basis.

Trade contractor appointment

A Blue project requires bespoke trade contractors that manufacture products specifically for the project (e.g. precast, windows) to actively participate in design chains with the architectural and engineering consultants. This has been shown to reduce trade prices by up to 20%. This allows design documentation to:

- Focus on commissioning/handover involving bespoke products;
- Incorporate manufacturing details;
- Eliminate shop drawings;
- Eliminate unnecessary variations from tender drawings which include impractical details;

- Be coordinated not just between consultants but also between trade contractors;
- Incorporate buildability and material handling.

These bespoke contractors typically number 4 to 7 per project and represent 60-70% of construction cost. Ideally these trade contractors should be appointed on a Design and Construct basis. However as there are no drawings to price, how can the builder proceed to negotiate a fair trade price without competitive tendering, prior to finalising the design? The following 3 options could be considered. Some of the options overlap and a hybrid answer could evolve.

Idea A
A contract with a trade contractor, which had successfully completed similar work for the builder, could be directly negotiated using costs from other projects as a benchmark. Targets can be agreed to lower cost by (say) 10% for eliminating tender costs (3%) and providing the opportunity to design out wasted effort (up to 20%). This establishes a panel of preferred suppliers who have proven themselves to be both trustworthy and focused on value adding.

Idea B
Provide preferred trade contractor with tender elemental budget, agree a profit margin, and jointly design to meet the budget on an open book basis.

This option involves:

- Preferred trade contractors being paid a fee to contribute to design and construction chain activity;
- Profit margins and contingencies for risk being pre-agreed;
- Business-as-usual trade site productivities and crew sizes being tabled as a benchmark on which to improve;
- Savings in site labour being shared between builder, trades and consultants;
- Material/equipment purchases done on an open book basis.

Idea C
Appoint a trade contractor for a fee to assist in design development and then either:

a. negotiate a fixed price with the fallback of tendering, or
b. tender from 3 pre-qualified trade contractors.

10. CONCLUSION

The FORM project demonstrated that creating a favourable project environment is crucial to creating extra wealth on projects by removing wasted effort. Although the project did not achieve the elusive Blue status (1 in 100), if the team had been able to move to another project, Blue was certainly possible.

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PERFORMANCE BASED BUILDING

Refereed Paper

HIGH QUALITY INDOOR ENVIRONMENTS FOR OFFICE BUILDINGS

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ABSTRACT

The quality of office indoor environments is considered to consist of those factors that impact the occupants according to their health and well-being and (by consequence) their productivity. Indoor Environment Quality (IEQ) can be characterized by four indicators:

- Indoor air quality indicators
- Thermal comfort indicators
- Lighting indicators
- Noise indicators.

Within each indicator, there are specific metrics that can be utilized in determining an acceptable quality of an indoor environment based on existing knowledge and best practice. Examples of these metrics are: indoor air levels of pollutants or odorants; operative temperature and its control; radiant asymmetry; task lighting; glare; ambient noise. The way in which these metrics impact occupants is not fully understood, especially when multiple metrics may interact in their impacts. It can be estimated that the potential cost of lost productivity from poor IEQ may be much in excess of other operating costs of a building. However, the relative productivity impacts of each of the four indicators is largely unknown. The CRC Project 'Regenerating Construction to Enhance Sustainability' has a focus on IEQ impacts before and after building refurbishment. This paper provides an overview of IEQ impacts and criteria and the implementation of a CRC project that is currently researching these factors during the refurbishment of a Melbourne office building. IEQ measurements and their impacts will be reported in a future paper

Keywords: office, air, thermal comfort, noise, lighting

1.0 BACKGROUND

The CRC for Construction Innovation initiated the project "Regenerating Construction to Enhance Sustainability" in 2005, with overall objectives:

- to re-life an office building to an "A Grade" office standard
- a 30 years' usage
- business case cash flows on a 16 - 20 year period
- an ecologically sustainable design
- a delivery method that is cost effective, and
- incorporation of best practice building and design technologies.

Specifically, the project outcome will be the delivery of superior refurbished **office** buildings according to a core set of four sustainability criteria:

- Eco-efficiency: minimising the ecological footprint of the refurbished building (compared to predecessor) within an agreed budget
- High indoor environment quality (IEQ): where the refurbished building has achieved demonstrable improvement in respect of key IEQ criteria, including thermal performance and indoor air quality
- Healthier and more productive working environment: as measured by the performance of occupants determined before and after refurbishment and
- Waste minimisation.

This report presents the research to date on the core sustainability criterion of **high indoor environment quality**. The research plan is to develop IEQ design guidelines by:

- Identifying and defining **key indicators** for high quality indoor environments
- Specifying **sampling and measurement protocols** for performance measures of key IEQ indicators
- Specifying reliable, **scientific procedures** by which the indicators can be measured at any location
- Recommending **performance criteria** for each indicator
- Consideration of **design and specification implications** of performance targets
- Documenting the implementation of the guidelines in a **target building before and after refurbishment**.

Other CRC researchers will investigate occupant impacts for the same target building, allowing IEQ-occupant interactions to be evaluated.

2.0 SELECTION OF IEQ INDICATORS

IEQ indicators (Brown and Kivlighon 2005) were considered to be encompassed in the following factors:

- indoor air pollutant levels
- thermal comfort
- lighting and
- noise.

Building ventilation rate will significantly impact these factors if uncontrolled, but since it is currently tightly regulated in BCA via Australian Standard 1668, it was assumed that that ventilation performance had been optimised for BCA requirements. A key consideration in selecting the indicators was that they could be represented by performance metrics relevant to impacts on occupant satisfaction and acceptance of office environments.

2.1 INDOOR AIR QUALITY INDICATORS

Poor indoor air quality (IAQ) can be a significant health, environment and economic problem, and has become a public health issue and liability for employers and building managers who fail to provide a 'safe' working environment. The meaning of IAQ is often interpreted differently across disciplines, but this report uses a broad definition for IAQ which has been generally accepted in Australia (Brown 1997, Environment Australia 2001, Brown 2005), which is 'the totality of *attributes* of indoor air that affect a person's health and well-being'. IAQ measures must thereby determine how well indoor air (a) satisfies thermal and respiratory requirements of occupants, (b) prevents unhealthy accumulation of pollutants, and (c) allows for a sense of well-being. International research has established the occurrence of a range of building-related illnesses, many with identifiable and diverse causes. A subset of these illnesses - termed the 'sick building syndrome' (SBS) - includes mainly subjective symptoms (mild irritation of eyes, nose and throat, headaches, lethargy). SBS symptoms are believed to arise from multiple causes which, while not clearly understood, are associated mainly with air-conditioned office buildings. Australian studies have been limited, but indicate similar occurrence to other developed countries for building-related illnesses, SBS-like symptoms and dissatisfaction with office air environments.

Regulatory actions related to indoor air quality in Australia are limited, especially in comparison to outdoor air quality and industrial workplace air, a feature also common overseas. Some guidance has been provided by authorities such as:

- the National Health and Medical Research Council (NHMRC), which has defined indoor air as the air within any dwelling, office, school or hospital where people spend more than one hour per day, and recommends health-based advisory IAQ goals
- the National Occupational Health and Safety Commission (NOHSC), which provides exposure guidelines for a large number of air contaminants in workplaces (only), which are generally called up in OHS regulation
- the World Health Organization (2000) which has recommended health-based environmental air quality guidelines for Europe, with application to both urban and indoor air exposures.

Table 1 provides comparative exposure or IAQ goal/guidelines from the above organizations and it is seen that there are substantial differences between occupational and environmental requirements. These arise because:

- occupational exposures occur for approximately 40 hours per week, whereas environmental exposures occur continuously (i.e. 168 hours per week, a factor of 4 higher than occupational exposure)
- the population health demographic of the workforce differs considerably from the general population which includes sectors with specific sensitivities to pollutants (e.g. infants, the elderly, people with asthma).

The protection of sensitive sectors of the population is considered appropriate when selecting IAQ guidelines for residential, health and educational building categories. Indicators for other building categories, especially office buildings, will need to consider the likely access by sensitive sectors of the population. For example, a government office to which the general public has access will need to apply an environmental guideline, while a private office accessible only to employees may choose to apply occupational guidelines depending on the health status of its employees.

A large number of pollutants have been investigated in Australian buildings, some in great detail, but for others few observations are available and it is not possible to determine exposure levels for the Australian population or the most appropriate strategies to reduce exposure (Brown 1997). Based on this background, key indicators of IAQ are recommended as in Table 2. Note that an order of priority has been assigned to each, according to the level of quality of indoor air that is likely to be achieved by their application in an office building where members of the public and children may have access.

Table 1 IAQ, environmental and occupational exposure goals for air contaminants

Pollutant	NHMRC IAQ goals		NOHSC Occupational Exposure Stds	NEPM Ambient Air Standards	WHO Air Quality Guidelines
	Goal	Meas. period			
Carbon monoxide (CO)	9 ppm	8 h	30 ppm (8h)	9ppm (8 h)	9 ppm (8 h) 25 ppm (1 h)
Nitrogen dioxide	-	-	3 ppm (8 h)	0.12 ppm (1 h) 0.03 ppm (1 y)	0.11 ppm (1 h) 0.02 ppm (1 y)
Lead	1.5 μg/m^3	3 mo	150 μg/m^3 (8 h)	0.5 μg/m^3 (1 y)	0.5 μg/m^3 (1 y)
Ozone	0.1 ppm	1 h	0.1 ppm (peak)	0.1 ppm (1 h)	-
	0.08 ppm	4 h	-	0.08 ppm (4 h)	0.06 ppm (8 h)
Radon	200 Bq/m^3	1 y	-	-	(100 Bq/m^3)
Sulphates	15 μg/m^3	1 y	-	-	-
Sulphur dioxide (SO_2)	0.25 ppm	10 min	2 ppm (8 h)	0.20 ppm (1 h)	0.18 ppm (10min)
	0.20 ppm	1 h		0.08 ppm (24 h)	0.04 ppm (24 h)
	0.02 ppm	1 y		0.02 ppm (1 y)	0.02 ppm (1 y)
Total Suspended Particulates	90 μg/m^3	1 y	-	-	-
PM2.5	-	-	-	25 μg/m^3 (24 h) 8 μg/m^3 (1 y)	Dose-response
Formaldehyde	120 μg/m^3 0.1ppm	peak	1 ppm (8 h)	50 μg/m^3 / 0.04 ppm (24 h)	100 μg/m^3 (30 min)
Total Volatile Organic Compounds	500 μg/m^3 (no VOC > 0.5 TVOC)	1 h	-	-	-
Benzene	-	-	1 ppm (8 h)	0.003 ppm / 10 μg/m^3 (1y)	carcinogen
Toluene	-	-	50 ppm	1 ppm (24 h) 0.1 ppm (1 y)	0.07 ppm / 260 μg/m^3 (1 week)
Xylene isomers	-	-		0.25 ppm (24 h) 0.2 ppm (1 y)	0.20 ppm / 870 μg/m^3 (1 y)
1,4-Dichlorobenzene	-	-	25 ppm	-	0.02 ppm / 134 μg/m^3 (1 year)
Dichloromethane	-	-	50 ppm	-	0.5 ppm / 3000 μg/m^3 (24 h)
Ethylbenzene	-	-	100 ppm	-	5 ppm / 22,000 μg/m^3 (1 year)
Styrene	-	-	50 ppm	-	0.06 ppm / 260 μg/m^3 (1 week)
Tetrachloroethylene	-	-	50 ppm	-	0.04 ppm / 250 μg/m^3 (24 h)
1,3,5-Trichlorobenzene	-	-	-	-	0.005 ppm / 36 μg/m^3 (1 year)
1,2,4-Trichlorobenzene	-	-	5 ppm	-	0.001 ppm / 8 μg/m^3 (1 year)

Table 2. Key indicators for indoor air quality

Indoor air pollutant	Possible sources	IAQ criterion (averaging period)	Priority
Formaldehyde	Partitions, furniture, shelving, flooring	100 μg/m^3 (peak)	High
Total VOC	Building materials, furniture, office equipment	500 μg/m^3 (1 h)	High
VOC: benzene	As for TVOC, auto exhausts	10 μg/m^3 (1 y)	High
VOC: toluene	"	4100 μg/m^3 (24 h)	High
VOC: xylenes	"	1200 μg/m^3 (24 h)	Low
PM2.5	Auto exhausts	25 μg/m^3 (24 h)	High
Carbon monoxide	Auto exhausts	9 ppm (8 h)	High
Carbon dioxide	Exhaled breath	800ppm (1h)	High
Ozone: at equipment exhausts	Copiers, printers	0.1 ppm	Low
Micro-organisms	Persistently damp surfaces, mechanical ventilation system	Absent on inspection	High
Asbestos	Insulation, sheeting, flooring	Inspection + risk evaluation	Low-Medium

2.2 THERMAL COMFORT INDICATORS

Thermal comfort is commonly defined as that 'condition of mind which expresses satisfaction with the thermal environment' (International Organization for Standardization (ISO), 1994). Since people vary greatly in physiological and psychological factors, it is accepted that it is impossible to satisfy the thermal comfort of all occupants. However, based on existing data it is possible to statistically define conditions that a specified proportion of **office** occupants will find thermally comfortable. As well as physical parameters - air temperature, radiant temperature, air speed, humidity - a person's activity levels and the insulation received from clothing will also influence thermal comfort but these are accepted at typical levels for office environments.

A significant factor to thermal comfort is whether a space is **mechanically** conditioned or **naturally** conditioned – these are known to require different conditions for thermal comfort since occupant expectations in the latter are shifted due to different thermal experiences and availability of individual control.

2.2.1 Mechanically conditioned offices

For given values of humidity and air speed, the thermal comfort zone can be defined in terms of operative temperature or in terms of combinations of air temperature and mean radiant temperature (American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 2004), defined as follows:

- operative temperature: the uniform temperature of an imaginary black enclosure in which an occupant would exchange the same amount of heat by radiation plus convection as in the actual nonuniform environment. In most practical cases, this can be calculated as the mean of the air temperature and the mean radiant temperature. Also, in the absence of radiant heating/cooling panels, heat generating equipment, envelope insulation and large window solar heat gain, the assumption that operative temperature equals air temperature is acceptable;

- air temperature: the temperature of air surrounding the occupant;
- mean radiant temperature: the uniform surface temperature of an imaginary black enclosure in which an occupant would exchange the same amount of radiant heat as in the actual nonuniform space.

The operative air temperature for buildings recommended by ISO (1994) was between 20°C and 24°C (22°C ± 2°C) for winter conditions and between 23°C and 26°C (24.5°C ± 1.5°C) for summer conditions, and these values were endorsed by the Australian Government (1995). The recent ASHRAE (2004) Standard 55 specifies operative air temperature according to two equivalent procedures: a simplified graphical method or a computer program based on a heat balance model; only the former will be presented. The graphical method may be applied to spaces where the occupants have activity levels between 1.0-1.3 met, where clothing provides 0.5 – 1.0 clo of thermal insulation, and air speeds are not greater than 0.2 m/s, **conditions that occur in most office spaces.** The range of operative temperatures presented in Figure 1 are for 80% occupant acceptability (based on 10% dissatisfaction for whole body and 10% for partial body comfort). Note that the thermal comfort zone extends across operative T from 19°C to 28°C, the specific operative temperature depending on clothing and humidity levels.

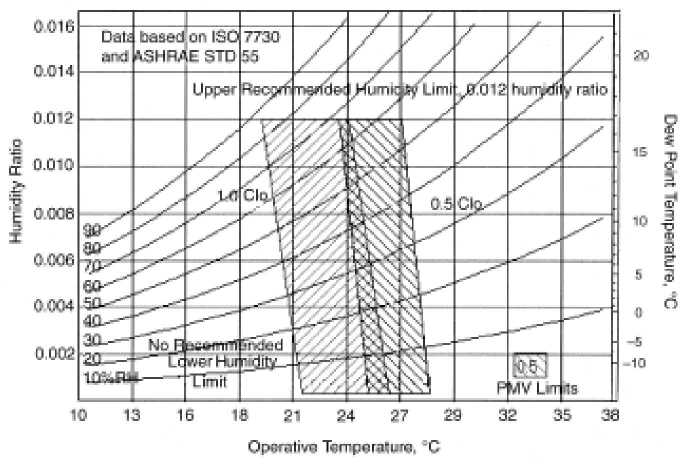

Figure 1. Acceptable ranges for operative temperature and humidity in 'typical' office spaces (ASHRAE 2004)

Relative humidity (RH) that is too high or too low can lead to skin, eye and respiratory irritation (ASHRAE 1992). ISO (1994) recommended that the relative humidity should be 30% to 70% for summer and winter conditions. ASHRAE (2004) considered that there was no lower humidity limit for thermal comfort but noted that there were non-thermal comfort factors to consider: skin drying, dry eyes, mucosal irritation and static electricity generation. The ISO lower limit (above) is considered appropriate to limit these factors. ASHRAE (2004) specified an upper humidity limit of a humidity ratio of 0.012 which corresponds to upper RHs of 55 – 85%RH. However, it is important to consider that relative humidities above approximately 70% can cause microbial growth and damage to surfaces within buildings, especially when condensation on surfaces occurs (Brown et al 1997). Hence it is considered that relative humidity in buildings should not exceed 70% RH.

An increased air speed can be useful as a means for decreasing body temperature although it needs to be sufficiently low so that it is not perceived by the individual as a draught. Also, a minimum air speed is needed so that localised accumulation of indoor air pollutants is prevented. Indoor air spaces have been found to have air speeds between 0.05 to 0.3 m/s (Christiansson et al 1989). ISO (1994) recommended that the mean air speed be less than 0.1 m/s, while ASHRAE (1992) recommended an air speed of less than 0.2 m/s for summer conditions. On this basis, it is considered that the air velocity should be within the range

0.05 – 0.2 m/s. Note that ASHRAE (2004) has specified that air speed may be increased above 0.2 m/s so as to increase the maximum temperature for acceptability **if occupants are able to control the air speed**. The amount of increase is limited to 3°C with air speed to not exceed 0.8 m/s. Another aspect of air speed is draught. ASHRAE (2004) specified a requirement based on the sensitivity of the head to a draught from behind. The relationship for draught unacceptable to 20% of occupants was provided for different levels of turbulence intensity. For the turbulence levels normally found in mechanically ventilated building, acceptable air speeds ranged from 0.15 to 0.3 m/s.

As the temperature at ceiling height is generally greater than the temperature at floor level, temperature as a function of height is considered as a factor that contributes to thermal comfort. ISO (1994) recommended that the vertical air temperature difference between 0.1 m and 1.1 m above the floor be less than 3°C for both summer and winter conditions. The recommended surface temperature of the floor was 19°C to 26°C. ASHRAE (2004) recommended that the temperature gradient not exceed 3°C between head and ankles (0.1 m and 1.7 m) levels, and also specified a floor surface temperature of 19°C to 29°C.

Radiant temperature asymmetry is caused by radiation differences resulting from hot and cold surfaces (for example, heat gain or loss through a window, influence of ceiling or wall temperature on room temperature). Temperature asymmetry may cause local discomfort and reduced thermal acceptability of a space. Also, occupants are generally more sensitive to asymmetric radiation caused by a warm ceiling than by that caused by warm or cold vertical surfaces. ISO (1994) recommended that the radiant temperature asymmetry from windows or other cold vertical surfaces to be less than 10°C (0.6 m above the floor) and from a warm (heated) ceiling should be less than 5°C. ASHRAE (1992) recommended radiant temperature asymmetry less than 5°C in the vertical direction and less than 10°C in the horizontal direction, these being the difference in radiant temperature at distances of 0.6 m and 1.1 m vertically and horizontally respectively. ASHRAE (2004) expanded the allowable radiant T asymmetry to be:

- warm ceiling < 5°C
- cool wall < 10°C
- cool ceiling < 14°C
- warm wall < 23°C.

ASHRAE Standard 55 and ISO 7730 both suggest the specification of three levels of acceptance for thermal comfort, since in practice the levels attained will depend on a range of factors: technical, cost, environmental, energy and performance. Table 3 shows the recommended levels of acceptance for three categories (B corresponds to ASHRAE's 1992 recommendation).

Table 4 lists criteria for general thermal comfort for the three levels of acceptance for several types of spaces (Olesen, 2004).

Table 3 Three categories of thermal environment

Thermal state of the body as a whole				**Local thermal discomfort**		
Category	**PPD %**	**Predicted mean vote**	**Draught rate, DR %**	**Vertical air temperature difference %**	**Warm or cool floor %**	**Radiant temperature asymmetry %**
A	< 6	- 0.2 < PMV < + 0.2	< 15	< 3	< 10	< 5
B	< 10	- 0.5 < PMV < + 0.5	< 20	< 5	< 10	< 5
C	< 15	+ 0.7 < PMV < + 0.7	< 25	< 10	< 15	< 10

Table 4. Criteria for operative temperature for typical buildings

Type of building	Clothing (clo)		Activity (met)	Category	Operative Temperature (ºC)	
	Summer	Winter			Summer	Winter
Office	0.5	1.0	1.2	A	24.5 ± 0.5	22.0 ± 1.0
				B	24.5 ± 1.5	22.0 ± 2.0
				C	24.5 ± 2.5	22.0 ± 3.0
Cafeteria / Restaurant	0.5	1.0	1.4	A	23.5 ± 1.0	20.0 ± 1.0
				B	23.5 ± 2.0	20.0 ± 2.5
				C	23.5 ± 2.5	20.0 ± 3.5
Department Store	0.5	1.0	1.6	A	23.0 ± 1.0	19.0 ± 1.5
				B	23.0 ± 2.0	19.0 ± 3.0
				C	23.0 ± 3.0	20.0 ± 4.0

Note that while the mean operative temperatures are the same for the different categories, the allowable spread of operative temperatures changes markedly across categories.

2.2.2 Naturally ventilated offices

Naturally conditioned spaces must be equipped with operable windows that can be readily opened and adjusted by occupants. There must be no mechanical cooling and mechanical ventilation may be present but window adjustment must be the primary means of regulating thermal conditions. The space may have a heating system but this indicator cannot be used if the heater is operating. Allowable indoor operative temperature may be determined from Figure 2, which includes limits for 80% and 90% acceptability. Note that this Figure is based on the adaptive model of thermal comfort that was derived from a global database of 21,000 measurements, mostly in office buildings (ASHRAE 2004). Also, this guidance applies only to conditions where the mean monthly outdoor temperature ranges from 10°C to 33.5°C. No guidance is allowable outside this range.

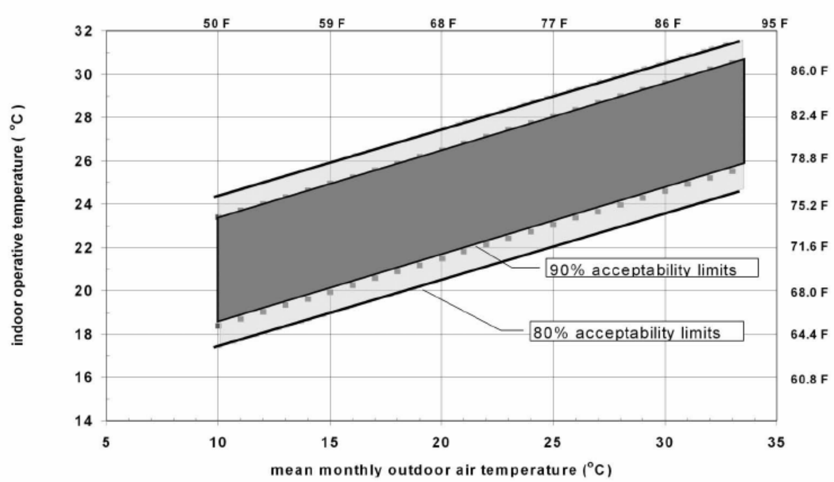

Figure 2. Acceptable operative temperature ranges for naturally conditioned spaces

2.3 LIGHTING QUALITY INDICATORS

Lighting levels need to be of a quality that provides an environment in which it is easy to see so that office tasks can be safely performed without eye strain. During typical working hours, lighting inside offices tends to rely on a combination of both daylight from windows and electric lighting. There is little doubt that people prefer to work by daylight and enjoy the view. Also, this mixture of lighting methods enables a degree of flexibility which is a useful outcome. Windows can assist in avoiding or reducing eyestrain by allowing an individual to focus on distant objects rather than prolonged viewing of close objects such as computer screens. However, the use of windows needs to be balanced with respect to any adverse thermal effects or unwanted lighting effects such as glare.

Even though a task may be three dimensional, it is generally carried out in more or less one plane and it is common to provide illuminance on that plane (called the 'working plane'). Note that achieving illuminances on working planes will facilitate the task visibility but does not necessarily achieve the desired visual appearance or comfort of a space. Also, in general there are three key factors to task illuminance:

1. increasing the illuminance on a task produces an increase in performance following a law of diminishing returns
2. the illuminance at which performance levels off is determined by the visual difficulty of the task (the smaller or the lower contrast in a task, the higher the illuminance level)
3. it is not possible to bring a difficult visual task to the same level of performance as an easy task simply by increasing the illuminance (e.g. consider the improvement from using a magnifier for tasks difficult to the unaided eye).

The standard international unit that is used to measure the amount of light per unit of surface area, also known as illuminance, is lux (symbolized lx). Australian Standards for interior lighting for office and screen based tasks recommend a minimum of 160 lx on the working plane so that eyes are not strained due to a deficiency of light. Also, the uniformity of illuminance within a room should not be less than 0.7 (i.e. the minimum illuminance on a given plane should not be less than 70% of the average illuminance). For general lighting systems, the recommended illuminances should be provided throughout the space on these horizontal planes (unless determined otherwise by a specific appraisal of a task):

- for tasks which are at desk height – 0.7 m above the floor
- for tasks at bench height – 0.85 m above the floor
- for tasks with surfaces that are not predominantly horizontal (e.g. filing, screen-based equipment), the recommended illuminances should be provided on these surfaces.

The visibility of a task is generally determined by the visibility of the most difficult element that must be detected or recognised – this is generally referred to as the critical detail and this will be influenced by many factors (e.g. size, colour, observation time, contrast, position, experience etc). Good task visibility depends on both the luminance of the task and its surroundings and optimum levels exist for the ratio of the luminances of task: immediate surrounds: general surrounds at approximately 10:3:1. Lighting levels lower than 160 lx are acceptable in infrequently occupied areas such as locker rooms, storage rooms and corridors, though the lighting differences of adjacent areas should not be pronounced (no more than 10:1) because of visual adaption factors.

The average *initial* illuminances for office-based tasks that should be provided by the lighting system will need to be significantly higher than the **recommended maintenance illuminance** in order to allow for the progressive loss of light due to:

- lamp ageing/dust accumulation
- dust accumulation on room surfaces
- dirt build-up on windows.

AS1680.2.2 specifies recommended values for maintenance illuminance as presented in Table 5.

Table 5. Recommended interior illuminance for office and screen-based tasks (note: lamp colour and glare factors also specified)

Task/room type	Recommended illuminance (lx)
General tasks: typing, reading, writing	
- task	320
- background	160
Screen-based task	
- keyboards	160
- reference material	
• good, simple	240
• average detail	320
• poor, fine detail	600
- background	160
- microform reading	20 – 40
Drawing offices	
- drawing board	600
- reference material	
• good, simple	320
• poor, fine detail	600
- background	240
Meeting rooms	320
Training/seminar rooms	240
Conference rooms/board rooms	240
Reception areas	
- enquiry desk	320
- entrance hall, lobby, foyer	160
Photocopying and printing room	
- Intermittent	160
- Sustained	240
- Colour	240
Filing area	
- clear detail	240
- fine detail	320

Glare is caused by an excess of light. Glare can cause eye fatigue/discomfort (also known as discomfort glare) and increasing amounts of glare can cause temporary vision impairment (also known as disability glare). Windows tend to be a more common source of glare than electric lighting. Where screen-based equipment is used, tasks require a direction of view closer to horizontal than for conventional desk work and so glare from lighting is of greater significance. AS1680.1 provides two alternative systems for control of discomfort glare:

- a luminaire selection system
- a glare evaluation system.

The latter is within the realm of indoor environment assessment, and provides a ***Unified Glare Rating*** (UGR, which is also specified in ISO 8995:2002 Lighting of Indoor Workplaces) that should be no greater than 19 for general offices:

$$\mathrm{UGR} = 8.\log\left(\frac{0.25}{L_b}.\sum\frac{L^2.\omega}{p^2}\right)$$

where L_b is the background luminance (cd/m^2), L is the luminance of the luminous parts of each luminaire in the direction of the observer's eye (cd/m^2), ω is the solid angle of the luminous parts of each luminaire at the observer's eye (steradian), p is the Guth position index for each individual luminaire which relates to its displacement from the line of sight.

AS1680.1 notes that glare can be more significant where one or more of the following exist:

- the room is large
- visual tasks are difficult and require sustained attention
- the direction of task view is at or above horizontal for significant periods
- room surfaces/equipment are abnormally dark or poorly lit.
-

The colour of light from a source is another point of consideration for the quality of the indoor environment. Colour temperature utilises the concept of a theoretical black body radiator. If a black body radiator is heated to approximately 3000 K, it emits light of a yellow-white colour, at 5000 K, it emits light of a blue-white colour. In general, rooms that are lit to less than or equal to 240 lx are best lit using an electric light that emits a warm colour temperature.

Flicker from electric lights can cause eye fatigue and is distracting. Flicker is most noticeable from electrical discharge lamps, most notably from fluorescent lamps. Electrical discharge lights use either an electronic or a magnetic ballast to supply enough voltage to allow current to flow. Magnetic ballasts do not change the input frequency of the power supply. Electronic ballasts can change the input frequency, which allows them to have the capability of changing the amount of flicker. It is recommended that fluorescent lighting have a high frequency (20 kHz – 60 kHz) electronic ballast. In addition to removing flicker, they are less likely to produce a high-pitched sound (Canadian Centre for Occupational Health and Safety, 2003). Frequencies lower than this recommendation can cause a buzzing noise and higher than the recommendation can lead to interference with radio waves (Australian/New Zealand Standard 60929: 2000, 2001).

2.4 SOUND COMFORT INDICATORS

Sound level is defined in terms of the unit decibel (A) which is measured at the frequencies over which humans generally hear, 20 to 20 kHz, using an 'A' filter (Australian Standard® 2659.1—1988, 1988). Equivalent continuous A-weighted sound pressure levels ($L_{Aeq,T}$) is a term that is used to indicate the sound level over a defined number of hours. For sound that is encountered during working hours, usually an 8 hour day, the continuous A-weighted sound pressure level is denoted by $L_{Aeq,8h}$. Background sound tends to be of a low intensity and is present for most of the time in any environment. Sources of background sound in an office include: computers, lights and ventilation systems. Excessive amounts of background sound can cause stress which can impede upon an individual's ability to work well. The UK's Sustainable Development Unit recommend that separate rooms/offices should have an $L_{Aeq,8h}$ value of less than 40 dB(A) and an open plan office less than 45 dB(A) (UK Government, 1999).

Impact sound is of a high intensity but lasts for only a short amount of time. Impact noise within in an office can come from sources such as electric staplers or doors slamming. High intensity impact noise can damage hearing, but it is considered highly unlikely to occur within an office environment, and so the averaged 8 hour noise level is an appropriate metric. Also, sound from short-term sources, such as printers and photocopiers, can be minimised by keeping them in a separate room. The WHO recommend that excessive sound should be controlled by first reducing the sound source, then reducing the sound propagation, and finally, protecting workers (Concha-Barrientos *et al.*, 2004).

Table 6 lists recommended A-weighted equivalent design sound levels in Australia (Australian Standard® 2822—1985, 1985), with a range given from satisfactory to maximum levels. The satisfactory design level is the amount of sound which is satisfactory for most people, while the maximum level is that which causes most people to be dissatisfied.

2.5 OCCUPANT QUESTIONNAIRE ON ENVIRONMENTAL COMFORT

While the above air and physical metrics aim to focus on the key indicators of IEQ, it is considered that the complexity of IEQ and the environment-occupant interaction is such that a direct feedback of occupant experience is also required in the assessment of IEQ. Applied to a statistically significant but random sample of occupants (approx. 30), this can provides a direct measure of the comfort levels experienced by occupants. Occupant experience was assessed with a two page questionnaire developed from the 'office environment survey' of Raw (1995) for the UK Health & Safety Executive. This is a self-administered questionnaire, applied by the occupants at the time of IEQ assessment, and has no questions related to measurement or assessment of productivity. Key questions relate to:

- Working conditions
- Discomfort from indoor climate in preceding two months
- Symptoms or health complaints in preceding two months linked to presence in office.

Table 6. Recommended A-weighted equivalent design sound levels and reverberation times for different uses within buildings

Activity/Occupancy type	Recommended design sound level $L_{Aeq,8h}$, dB(A), (Satisfactory – Maximum)	Recommended reverberation time(s)*
Board and conference rooms	30 – 40	0.6 to 0.8
Cafeterias	45 – 50	*
Call centres	40 – 45	0.1 to 0.4
Computer rooms	45 – 50	*
Corridors and lobbies	45 – 50	0.4 to 0.6
Design offices	40 – 45	0.4 to 0.6
Draughting offices	40 – 50	0.4 to 0.6
General office areas	40 – 45	0.4 to 0.6
Private offices	35 – 40	0.6 to 0.8
Public spaces	40 – 50	0.5 to 1.0
Reception areas	40 – 45	*
Rest rooms and tea rooms	40 – 45	0.4 to 0.6
Toilets	50 – 55	—
Undercover carparks	55 – 65	—

* It is recommended that reverberation time be minimised as much as possible.

3.0 APPLICATION TO AN OFFICE REFURBISHMENT

Melbourne City Council owns an office building in Melbourne city centre that has three lower levels of carparking, six levels of offices occupied by its staff, and a plant room on the 10th level. This building was constructed approx. 1970 and is planned to be upgraded and refurbished in 2006. Refurbishment will result in the same six levels remaining as offices (though with substantial changes to layout, ventilation, windows etc) and the CRC project focus is only on these offices, though the impacts from surrounding environments (e.g. car exhausts from enclosed car parks on levels 1-3; noise from outside traffic or proposed roof-top occupancies) were considered in design of the measurement protocol. Overall, it was considered that IEQ assessment must be carried out both before and after refurbishment, in each case for two seasons (summer and winter), and as close as possible to the building refurbishment. Assuming that the six levels of offices had a common air supply system and occupants had similar tasks/activities before and after refurbishment, measurements and criteria were recommended as in Table 7. All factors are to be measured over 5-8 consecutive work days, with the building fully occupied and within business hours. These measurements will be presented in future reports.

Table 7. IEQ assessment plan for Melbourne City Council CH1

IEQ Factor	Measurement location(s)			Sample time		Criteria for high performance
	levels	locations	out-door	sample	sample days	
IAQ						
TVOC	1,4,6	2	1	1h	2	500 μg/m^3 (1h)
Benzene	1,4,6	2	1	1h	2	10 μg/m^3 (1h)
Toluene	1,4,6	2	1	1h	2	4100 μg/m^3 (1h)
Formaldehyde	1,4,6	2	1	0.5h	2	100 μg/m^3 (0.5h)
PM2.5	1,6	2	1	8h	5	25 μg/m^3 (8h)
CO	1,6	2	1	8h	5	9 ppm(8h), 25ppm(1h)
CO2	1,6	2	1	8h	5	800 ppm (1h)
Microbial	1,6	20	-	-	-	none visible
Ventilation						
Effective air changes/h (ACH)	1,4,6	1	-	1h	2	< 1 ACH infiltration > 2 < 6 ACH w/mech.
Thermal Comfort						
Operative T	1,4,6	5+	1	8h (total)	5	Fig1 or Fig 2 (90% satisfaction achieved)
Air velocity	1,4,6	5	-	2 min	5	0.05-0.2 m/s (2 min)
RH	1,4,6	2	1	8h	5	30-70% (1h)
Thermal gradient	1,4,6	5	-	2 min	2	<3°C (2 min)
Floor T	1,4,6	5	-	2 min	2	19-29°C (2 min)
Radiant T assym (0.1-0.6m)	1,4,6	5	-	2 min	2	warm ceiling < 5°C cool wall < 10°C cool ceiling < 14°C warm wall < 23°C
Lighting						
Illuminance (min)	1,4,6	6+	-	2 min	3	>160 lx
Task illuminance	1,4,6	8+	-	2 min	3	160-600lx (Table 5)
Glare	1,4,6	4+	-	2 min	3	UGR < 19
Noise						
Sound level $L_{Aeq,T}$,	1,4,6	5+	-	1h	3	Table 6
Reverberation time	1,4,6	2	-	1h	1	Table 6
Occupant Comfort Survey	1,4,6	30	-	4h	1	<20% complaint rate

4.0 CONCLUDING REMARKS

A range of physical and air pollutant factors have been selected for measuring IEQ in office buildings relevant to their impacts on occupant satisfaction and acceptance of office environments. These have been measured in a target building in the winter of 2005 without significant problems or inconsistencies. The second season measurements will be carried out in summer 2005, just prior to the refurbishment commencing. After refurbishment, it is expected that measurements will be repeated approximately 1-2 months (summer) and 6-7 months (winter) after occupancy of the building. The impact of refurbishment on occupants' productivities is being assessed within another part of the CRC project and the linkage between the IEQ metrics and occupant experience will be explored in the final phase of the project.

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CONSTRUCTION HEALTH AND SAFETY

Refereed Paper

SUPPORTING THE DESIGN OHS PROCESS: A KNOWLEDGE-BASED SYSTEM FOR RISK MANAGEMENT

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ABSTRACT

In some Australian jurisdictions (Western Australia, South Australia, Queensland and Victoria), specific obligations for OHS designers of buildings and structures have been established in the legislation. However, it is far from apparent that construction design professionals possess the OHS knowledge, skills and abilities they need to comply. Knowledge-based systems (KBSs) seek to replicate, by computer, the problem solving expertise of human specialists. KBSs are ideally suited to providing OHS decision support because OHS is a specialist area in which it is undesirable to learn from one's mistakes. Two ways in which KBSs have been successfully used to aid OHS decision-making are in the provision of regulatory advice and in supporting the OHS risk management process. This paper describes a project currently underway to design, develop and rigorously evaluate a knowledge-based decision support tool to assist construction designers to manage OHS risks in the design process. The conceptual design of the decision support tool is described and an example provided to demonstrate the use of a Generic Actual Argument Model to represent design OHS knowledge.

Keywords: **Occupational health and safety, design, decision support, argumentation theory, risk management, knowledge-based systems**

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1.0 INTRODUCTION

1.1 DESIGN OHS

According to theories of risk management, the most effective way to manage a risk is to eliminate or reduce it at source. Within the construction industry, this 'source' is the design team (Martens 1998) and there is compelling evidence to suggest that decisions made during the design stage of a project can have a significant impact upon OHS during the construction, occupation, maintenance and demolition stages of a building's life cycle (Williams 1998; Maxwell, 2004; HSE 2003; Commission of the European Communities 1993). Construction design professionals have considerable opportunity to eliminate or reduce OHS risks throughout the life cycle of the buildings or structures they design. Designers make choices about the methods of construction and materials used, which can significantly impact upon OHS of those who build, occupy, maintain, clean, renovate, refurbish or eventually demolish a building or structure (ECI 1996; Hinze and Gambatese 1994).

The importance of design OHS has been recognised by policy-making bodies and legislators, in Australia and elsewhere. The Australian National Occupational Health and Safety Commission (NOHSC 2003) identified design as a critical factor in occupational injuries and fatalities, and established design OHS as an area of national priority in the National OHS Strategy 2002–2012 (NOHSC 2002). Specific obligations for construction designers have been included in the preventive OHS legislation in four Australian states (Western Australia, South Australia, Queensland and Victoria (Bluff, 2003) and the adequacy of designers' OHS responsibilities is an issue currently under review in New South Wales.

However, enactment of such legislation does not automatically deliver a reduction in OHS risk. The case of UK OHS design legislation, enacted in 1995, reveals that there is a fundamental lack of knowledge and appreciation among designers surrounding the OHS consequences of their designs (Summerhayes 2002). Further research suggests that the majority of UK designers do not treat OHS as a priority and design risk assessments are of poor quality (Rigby 2003; Entec, 2000). Likewise, it is doubtful that Australian construction designers are, at present, sufficiently well informed about ways in which OHS risks arising as a result of their design can be identified, assessed and controlled. Australia is therefore in a position to learn from the experience of the UK, and develop tools that help construction designers to better integrate OHS risk management into the design process.

This paper presents the conceptual design for an innovative IT application that is being developed to assist construction designers to integrate OHS into their design decision-making. It describes the mechanism by which OHS knowledge will be modelled and presented to design professionals.

1.2 KNOWLEDGE-BASED SYSTEMS IN OCCUPATIONAL HEALTH AND SAFETY

Knowledge-based systems (KBSs) seek to replicate, by computer, the problem solving expertise of human specialists in a specific area of application. KBSs are ideally suited to providing OHS decision support because OHS is a specialist area in which it is undesirable to learn from one's mistakes. The deployment, through software, of OHS expertise that would otherwise be unavailable to the decision-maker can be of considerable benefit in the management of OHS (Roberston and Fox 2000). Two ways in which KBSs have been successfully used to aid OHS decision-making are in the provision of regulatory advice and in supporting the OHS risk management process. Given the lack of OHS expertise among construction designers, a knowledge-based decision support application has considerable potential to ensure that designers integrate OHS risk management into their design decision-making.

1.3 KNOWLEDGE-BASED SYSTEMS IN DESIGN

Knowledge-based decision support tools have previously been demonstrated to improve decision-making and enhance the efficiency and productivity of designers. For example, Berrais (2005) describes a system for the provision of expertise relating to the design of earthquake resistant reinforced concrete buildings. This system ensures that designers who have little or no experience in earthquake zones are able to consider all of the relevant factors in their design decision-making.

Knowledge intensive computer-aided design (KIC) systems have also been developed to provide knowledge that has a bearing on the design process accessible to designers (Mantyla, 1995). KIC systems have been used to provide expertise, standards and regulations relevant to the resolution of design problems. For example, Yip *et al* (2005), deployed machine learning algorithms to model the airflow and heat retaining properties of toaster cases and predict the performance of a newly designed toaster, thus obviating the need for a physical prototype. Likewise, the Building and Construction Authority of the Singapore government has applied artificial intelligence techniques for the automated assessment of plans against building regulations in a system known as CORENET (www.corenet.gov.sg). In CORENET, building elements are represented using the International Alliance for Interoperability's (IAI) Industry Foundation Classes (IFC) and include rooflights, vertical windows and roof slabs. The CORENET knowledge base represents building regulations as rules that apply to building entities and their properties. During an automated plan checking session, the rules associated with each building entity are interrogated in order to identify breaches of the building regulations.

Davison (2003) reports on the development of a prototype that deploys a similar automated plan checking technology to provide knowledge-based advice on OHS in building design. Elements are encoded as IFC's but, rather than apply building regulation rules to identify breaches, OHS rules are applied to identify risks inherent in the use of each building entity. A designer using this prototype can initially view textual information, including relevant legislation, regulations and cases. Then, risks associated with the building's life cycle (including construction, maintenance, use and demolition) are identified and assessed during a rule checking phase. This British prototype uses a large number of IF-THEN rules as the basis upon which to solve problems.

The paper briefly describes the research and development (R&D) process being used to deliver the Australian design OHS decision support prototype, before focusing on the novel method of modelling OHS knowledge that will be deployed. The advantages of this novel knowledge representation approach over traditional rule-based systems (such as those deployed by Davison (2003) and in the Singaporean CORENET system) are discussed.

1.4 THE PROTOTYPE DEVELOPMENT PROCESS

An R&D project is currently underway to develop a prototype tool to provide practical, user-friendly OHS advice, enabling designers to manage the risk of falls from height arising from their design decisions. The project will:

- Develop a model of best practice reasoning used by building designers when assessing and reducing the OHS risk posed by their designs. The model will initially be limited to the risk of falls from height during the use and maintenance stages of a building's lifecycle.

- Implement the model as a web based decision support system. Designers will step through a sequence of questions about their design. The system will make an assessment of falls from height risks associated with a design.
- Trial the decision support tool among a sample of construction design professionals and evaluate the outcomes.

The R&D project is being carried out in the three stages briefly described below.

Stage 1: Knowledge acquisition

This stage involves collecting the data that will underpin the decision support tool. Teams of experienced construction designers will participate in workshops facilitated by an OHS expert. Workshops will also be attended by groups of facilities managers, representing building users and maintenance personnel to ensure that the OHS risk experience and knowledge of these parties is adequately captured. The workshops will seek to:

- identify 'falls from height' hazards introduced by design decisions;
- assess the OHS risk presented by these 'falls from height' hazards; and
- provide advice as to how the risk of falling from height could be reduced through design modifications.

Once collected, this knowledge will be structured to create a series of 'argument trees.' These trees represent the hierarchy of factors which are believed (by the experts involved in the Step 1 workshops) to be relevant to the determination of OHS risk and the choice of risk control measure. These argument trees represent the expertise that will form the basis of the decision support tool and it is critical that all relevant factors are represented. Prior to the development of the decision support tool, the argument trees will be validated. The argument trees will be presented to a second group of experts to ensure that all the relevant factors that need to be considered in the risk assessment and control decisions of construction designers are reflected. The argument trees will be modified as necessary until consensus is reached.

Stage 2: Prototype development

A prototype decision support tool will be 'built.' Initially, within the scope of this project, a 'stand-alone' tool will be delivered, but it is envisaged that eventually the decision support application will be linked to Computer Aided Design (CAD) applications, such that designs created in CAD applications can be 'uploaded' and subject to an automatic on-line risk assessment. Designers will then be alerted as to those OHS risks that exceed a threshold value and prompted to reduce these risks according to preferred options in the 'hierarchy of controls.' This hierarchy arranges OHS measures in order of priority from the most effective to the least effective.

Stage 3: Evaluation of the prototype

Finally, a group of construction designers will be required to use the tool and undertake a formative evaluation of its impact. The evaluation will consider issues of user-friendliness, practical benefit and the extent to which the tool results in practical risk reduction for falls from height. In determining the tool's potential to reduce OHS risks, a group of building users, facilities' managers and maintenance workers will perform a *post hoc* evaluation of design decision-making in a series of case study projects.

2.0 INNOVATION IN KNOWLEDGE MODELLING

2.1 LIMITATIONS OF RULE-BASED SYSTEMS

Despite the excitement surrounding the development of early expert systems, the commercial deployment of rule-based knowledge-based systems has been problematic. Reasons for this lie partly in the fact that such systems are often cumbersome and slow. Rule sets that underpin real world problems are typically large (10,000 rules is not exceptional) and difficult and time consuming to elicit from experts. The development of many early expert systems was halted because of the enormous time required by knowledge engineers to interview experts, translate their knowledge into rule sets and validate the resulting rules. Lenat (1983) coined the phrase 'knowledge acquisition bottleneck' to describe this problem. Associated with the large number of rules required to adequately represent factors influencing real world decision-making was the speed of early, rule-based knowledge-based systems. Inference engines that chain through large rule sets rapidly enough for real time and even web based applications are very difficult to develop.

Problems also arise as a result of the fact that real world problems are often too complex to be adequately represented in the form of simple "IF-THEN" rules. Rule sets do not easily encode uncertain or discretionary knowledge and inference engines do not elegantly infer with uncertainty attached to rules. The issue of 'open texture' (i.e. the indeterminate nature of concepts) presents a particular problem in the use of rules to represent knowledge relating to legal reasoning and compliance.

Although rule-based knowledge-based systems have made a significant contribution towards the development of computational models of reasoning, it is now widely accepted that reasoning represented as rules is applicable only in highly structured and narrowly contextualised situations. Consequently, knowledge-based systems which represent knowledge as rules are not well suited to the application of OHS because the management of OHS risk is characterised by professional judgement and discretionary decision-making.

2.2 DESIGN OHS LEGISLATION

OHS legislation provides duty holders with considerable discretion. Flick (1979) defines discretionary domains as those in which in which a decision maker has the freedom to select one interpretation or outcome from a number of permissible options. Dworkin (1977) proposes two basic types of discretion, which he calls strong and weak discretion. Weak discretion describes situations where a decision-maker must interpret standards in his/her own way, whereas strong discretion characterises those decisions in which the decision-maker is not bound by existing standards but is required to create his or her own standards. Both types of discretion apply to varying degrees in modern OHS legislation.

The provisions of early OHS legislation in Britain and Australia were detailed and prescriptive, allowing for little discretion on the part of duty-holders. The legislation clearly specified what must be done in order to comply. However, in 1972, a British committee of inquiry headed by Lord Robens recommended a reduction in the prescriptive detailed legislation. These recommendations were followed in 1974 when, in Britain, the Health and Safety at Work Act was enacted. Under the influence of Robens, prescriptive OHS Acts and Regulations were replaced by legislation containing 'general duties' for those whose actions impact upon OHS, including employers, employees, and suppliers of industrial plant and materials. Australia followed the Robens model, with the introduction of Robens-inspired legislation in South Australia (1972), Tasmania (1977), Victoria (1981), New South Wales (1983), Western Australia (1987), Queensland (1989) and the Northern Territory (1986). General duties provisions now exist in the principal OHS Acts of all Australian states and territories. Most recently, in some Australian jurisdictions, general duties for construction designers have been added to the OHS legislation. The 'general duties' legislation differs from the prescriptive early legislation in it does not clearly spell out the methods by which legislative compliance is to be achieved. Thus, the general duties require interpretation, judgement and discretionary decision-making.

Moreover, the general duties are not absolute, being qualified by vague terms like 'so far as is reasonably practicable.' For example, section 28 of the Victorian Occupational Health and Safety Act (2004) requires that:

> *"A person who designs a building or structure or part of a building or structure who knows, or ought reasonably to know, that the building or structure or the part of the building or structure is to be used as a workplace must ensure, so far as is reasonably practicable, that it is designed to be safe and without risks to the health of persons using it as a workplace for a purpose for which it was designed."*

The standard for construction designers' OHS duty is therefore 'what would a reasonable designer have done in the situation?' It is reasonable to expect that as the risk to health and safety increases, the degree of effort exerted in controlling the risk should also increase. Thus, in order to ascertain what is reasonable in a given situation a design risk assessment is necessary.

2.3 RISK MANAGEMENT

The risk management process is similarly characterised by professional judgement and discretionary decision-making. AS/NZS 4360, *Risk Management*: 2004, sets out the steps in the risk management process. These steps (depicted in Figure 1) involve analysing the context in which the risk arises, identifying, analysing and evaluating risks and deciding how to treat risks. Risk assessment includes the identification, analysis and evaluation stages in the risk management process (Standards Australia, 2004).

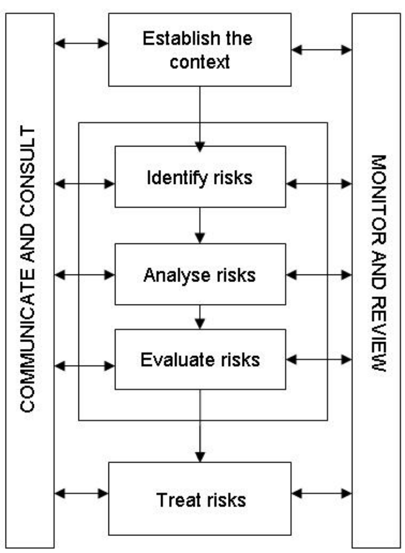

Figure 1: The risk management process (adapted from HB205-2004)

Risk is understood to be a function of likelihood and consequence of an undesirable event, such as a work-related incident. In most instances, reliable quantitative risk data are not available to undertake objective, probabilistic assessments of OHS risks. OHS risk assessments are usually qualitative and characterised by considerable subjectivity. Consequently, the value of a risk assessment is limited by the knowledge and experience of the risk assessment team. Decisions about risk tolerance and appropriate means for risk reduction are also inherently subjective (Pidgeon et al 1993). Where risks are deemed to be unacceptably high, decisions must be made about how to treat or control these risks. In the case of the most serious risks, a decision-maker might decide not to proceed with an activity, for example eliminating a hazardous design element from a design. An example would be the decision made to stop using asbestos sheeting for the construction of buildings once the risks posed by the material became apparent. However, in the case of most OHS risks, steps can be taken to reduce the level of risk. Risk reduction measures are selected according to an established 'hierarchy' of risk control measures, which holds that it is better to eliminate a risk or 'design out' a risk than to control it using measures that are reliant on safety procedures, training or the use of personal protective equipment. An example hierarchy for the risk of falling from height is provided in Table 1.

2.4 ALTERNATIVE MODELLING APPROACHES

The primary innovation in the development of the Australian design OHS decision support prototype is the use of 'argumentation theory' in the representation of knowledge. In contrast to the rule-based approach adopted by Davison (2003) in the UK, design OHS knowledge will be captured and represented as a series of 'argument trees'. An example design OHS argument tree is presented in Figure 2. The use of 'argument trees' to represent expert knowledge was pioneered in a model of reasoning developed by Yearwood and Stranieri (2005) and has been successfully used to structure and represent knowledge in various fields of legal reasoning, including family law, refugee law and eligibility for LegalAid.

In the case of the design OHS prototype, each argument tree will represent a hierarchy of factors relevant to the determination of a design-related OHS risk. The 'root' of each tree will be the OHS risk rating associated with a particular design element and/or activity. The risk rating will be inferred with knowledge of two factors: the likelihood that an injury or illness will occur; and the likely severity of the consequence of that injury or illness should it occur.

For example, the distance of fall and the availability of anchorage points for fall arrest devices are likely to be relevant factors that lead to an inference describing the consequence of a fall (i.e. the severity of the injury). The availability of anchorage points is conceptually related to the consequence rather than the likelihood of a fall because, in OHS theory, fall arrest equipment will not prevent a fall from occurring but will limit the consequence of a fall if one does occur. The frequency with which workers must go on the roof to perform maintenance, the number of skylights, the strength of the skylight material, the roof pitch and protection for roof maintenance might be used to infer the likelihood that a fall will occur during maintenance work. Throughout the argument trees, a linguistic variable value on a 'parent' node will be inferred from values on 'children' nodes with the use of pre-determined and appropriate inference procedures. For example, the risk rating is inferred using a multiplicative function for numeric variables derived from the values for the children 'likelihood' and 'consequence' nodes.

Argument trees are somewhat similar to fault trees and event trees that have been traditionally used to represent the interaction of events that have already contributed to safety incidents or which could lead to adverse safety outcomes in the future. However, argument trees differ to the extent that they do not begin with a specific incident (fault tree) or map the pathways from an in initiating event to an identified outcome (event tree). Instead, argument trees are a particular type of logic diagram representing the relevant factors that an expert would consider in making an assessment or judgement about something, in this case in assessing an OHS risk. By specifying 'values' for each node in the tree, a risk rating can be inferred, using the same logic and reasoning that an expert would use.

In argumentation-based KBSs, different inference mechanisms can be used according to the nature of knowledge being modelled. For example, in the '*Split Up*' system (described in Stranieri *et al* 1999), neural networks trained on data drawn from divorce property judgements were used to infer about half of the 35 nodes. In a different system, known as '*Embrace,'* which supported the determination of someone's refugee status, inferences were always left to the discretion of the decision-maker (Yearwood and Stranieri 1999). In another system called *GetAid,* Stranieri et al (2001) assigned weights to each linguistic variable and then summed these weights before comparing the result with a pre-determined threshold to infer eligibility for legal aid. The mechanisms to be used to infer values on the 'parent' nodes from values on the 'children' nodes in the design OHS prototype have yet to be determined, but it is likely that several different types of inference mechanism will be used.

The representation of design OHS knowledge in this way is highly innovative and much better able to model the subjective and discretionary nature of OHS risk management than the rule-based approaches deployed in other OHS knowledge-based decision support tools.

Argument trees represent a template for reasoning in complex situations. Thus, in a discussion about the level of risk posed by a particular design decision, two designers might disagree at the root node level. For example, one designer may perceive the risk to be high while another perceives it to be moderate. This difference in perception may derive from the different values assigned by each designer to subordinate nodes in the argument tree. For example, one designer may believe that the protection provided for roof maintenance is adequate, whereas another may not. However, although the two designers disagree, they can both accept the argument tree structure as a valid template for the derivation of their subjective risk assessments.

Thus, argument trees are intended to capture a shared understanding of relevant factors in the determination of a value (in this case the level of OHS risk). Irrelevant factors are not included in an argument tree. Thus, the colour of the roofing material is not considered relevant by design OHS experts, so is not represented as a node in the tree. (Although one can imagine circumstances where colour is indeed relevant to OHS, such as in the specification of emergency or warning signage).

The search for suitable measures that will reduce the risk level at the root node of the argument tree can also be automatically elicited from the tree itself. For example, a possible solution could be found by changing leaf node values until the desired level of risk emerges at the root node. Changing the protection for roof maintenance to 'adequate', decreasing the number of skylights or providing suitable anchorage points for fall arrest devices may result in a level of risk that is acceptable (for example, Low).[2] If not, then changing the value for other leaf nodes may reduce risk to a pre-determined tolerable level. It is worth noting that when knowledge is modelled in this way, the search space of all leaf node value combinations will provide a list of all possible risk control solutions to each identified design OHS hazard.

[2] Note that the argument tree presented in Figure 2 is an example used to illustrate a concept. It is not based upon validated data and should not be used to assess risk or select appropriate control measures.

Table 1: Example risk control hierarchy for the risk of falling from height (Lingard and Rowlinson 2005)

Risk Control Category	Control Measures
Eliminate the hazard	Structures should be constructed at ground level and lifted into position by crane (eg. prefabrication of roofs or sections of roofs).
Substitute the hazard	Non-fragile roofing materials should be selected.
	Fragile roofing material (and skylights) should be strengthened by increasing their thickness or changing their composition.
Isolate the process	Permanent walkways, platforms and travelling gantries should be provided across fragile roofs.
	Permanent edge protection (like guard rails or parapet walls) should be installed on flat roofs.
	Fixed rails should be provided on maintenance walkways.
	Stairways and floors should be erected early in construction process so that safe access to heights is provided.
Engineering controls	Railings and/or screens guarding openings in roofs should be installed before roofing work commences.
	Temporary edge protection should be provided for high roofs.
	Guard rails and toe-boards should be installed on all open sides and ends of platforms.
	Fixed covers, catch platforms and safety nets should be provided.
	Safety mesh should be installed under skylights.
Safe working procedures	Only scaffolding that conforms to standards should be used.
	Employers should provide equipment appropriate to the risk like elevated work platforms, scaffolds, ladders of the right strength and height, and ensure that inappropriate or faulty equipment is not used.
	Access equipment should be recorded in a register, marked clearly for identification, inspected regularly and maintained as necessary
	Access and fall protection equipment such as scaffolds, safety nets, mesh etc should be erected and installed by trained and competent workers.
	Working in high wind or rainy conditions should be avoided.
	Employers should ensure regular inspections and maintenance of scaffolding and other access equipment, like ladders and aerial lifts.
	Employers should ensure that scheduled and unscheduled safety inspections take place and enforce the use of safe work procedures.
	Employees should be adequately supervised. New employees should be particularly closely supervised.
	Employees should be provided with information about the risks involved in their work.
	Employers should develop, implement and enforce a comprehensive falls safety program and provide training targeting fall hazards.
	Warning signs should be provided on fragile roofs.
	Ladders should be placed and anchored correctly.
Personal protective equipment	Employees exposed to a fall hazard, who are not provided with safe means of access, should be provided with appropriate fall arrest equipment such as parachute harnesses, lanyards, static lines, inertia reels or rope grab devices.
	Fall arrest systems should be appropriately designed by a competent person.
	Employees should be trained in the correct use and inspection of PPE provided to them.
	Employees should be provided with suitable footwear (rubber soled), comfortable clothing and eye protection (for example, sunglasses to reduce glare).

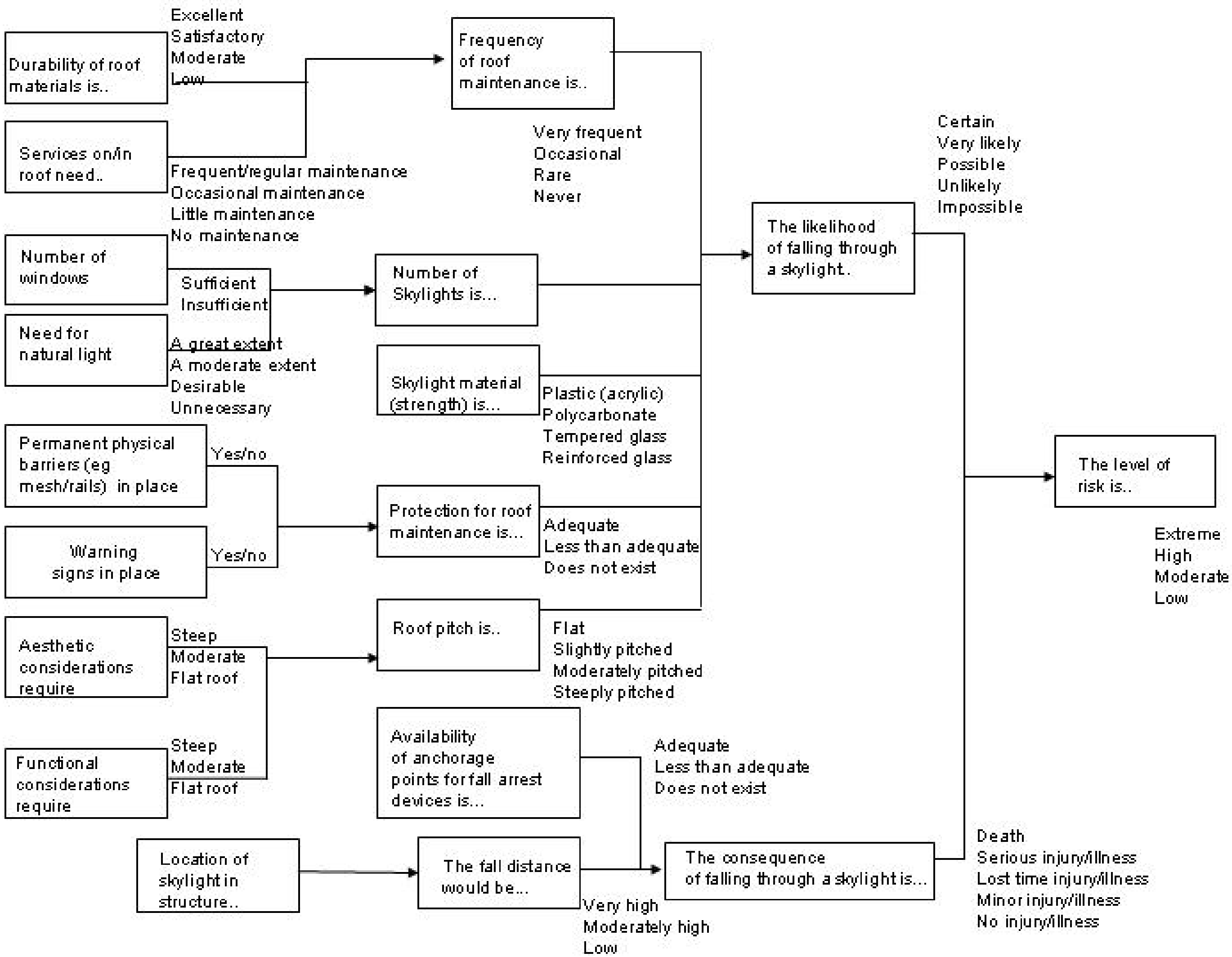

Figure 2: Example 'Argument Tree' for the risk of falling through a skylight while undertaking roof maintenance

The argument tree approach to knowledge representation provides a simple structure for the assimilation of OHS knowledge into the construction design process. The advantages of this structure include:

- The risk rating (eg extreme) is not 'hard coded' and attached to each rule but the end value will be generated via validated inference procedures embedded within the tree itself;
- Possible solutions to high risk issues are not hard-coded (and therefore restricted). Rather, a search procedure can generate and test solutions by changing leaf nodes (i.e. base facts) and invoking inference procedures up the tree to ultimately generate a lower risk option; and
- Many rules are replaced by a single tree, resulting in a system that is easier to use and maintain. For example, as construction technology advances and new design solutions to OHS risks become known, relevant concepts and values can be relatively easily added into the argument trees. Also, where applicable, rule sets may be embedded in an inference procedure within any level of the tree. However, the use of the tree also enables mechanisms for drawing inferences, other than rules, to be deployed. This enables the approach to integrate a variety of existing inference methods and more readily accommodate inference methods yet to be discovered.

3.0 CONCLUSIONS

This paper describes the conceptual design of a decision support tool to support construction design professionals in integrating OHS risk management into the design process. This is important because, experience in the UK has shown that construction design professionals are ill-equipped to manage OHS risks arising from the design process. OHS is typically not taught to construction design professionals in tertiary institutions within Australia and, thus, Australian design professionals' may similarly lack the OHS and risk management knowledge, skills and abilities they need to comply with their statutory OHS duties. The R&D project currently underway adopts an innovative approach to modelling knowledge that is better suited to situations of discretionary decision-making and professional judgement than the rule-based systems of the past. As such, the project promises to make user-friendly, expert OHS knowledge readily available to construction design professionals.

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