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Time-based Performance Improvement.

**- A Methodology for the Diagnosis of Processes and
Design of Performance Improvement Solutions.**

Executive Summary.

by

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A thesis submitted in partial fulfilment of the requirements for the degree of
Doctor of Engineering.

University of Warwick, School of Engineering, Warwick Manufacturing Group.

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Declaration.

This thesis is the work of Paul Anthony Chapman except where clearly stated otherwise. It does not contain any work previously submitted for a degree.

This thesis includes case studies based on industrial based projects undertaken by the author whilst a member of various teams. The case studies are the work of Paul Chapman, except where stated otherwise. The underlying material however includes content originating from other team members. Where attributable, these contributions are acknowledged. To clarify, the principle contribution of this author in these teams was to provide the methodology for undertaking an improvement project, facilitate the project team through this methodology and through the application of the appropriate techniques and tools. In addition, this author audited data, findings and conclusions stemming from the project teams. In practice, this involvement extended to include demonstrating aspects of the methodology in-situ, including data gathering and analysis.

The thesis includes material arising from work on the thesis undertaken during the period of study that was accepted for publication before the thesis was completed. This material is contained in the paper, Chapman, P., James-Moore, M., Szczygiel, M and Thompson, D., "Building Internet Capabilities in SMEs," which has been accepted for publication in the journal, Logistics Information Management. Whilst there are four authors named on this work, the principal researcher and author was Paul Chapman.

Paul Chapman

Dated

Abstract.

Performance improvement is an activity that all organisations must undertake to gain competitive advantage or simply to maintain parity with the progress of competitors. Such improvement efforts are frequently undertaken in an ad-hoc manner. These are usually ineffective, with projects failing to improve the aspects of the organisation that deliver customer value, and inefficient with resources being wasted. In response to this situation, a methodology was developed to aid business processes diagnosis and to design appropriate improvement projects that possess the potential to deliver exceptional improvement.

The methodology was designed using time as the key performance metric for analysing business processes and practices. This time-based approach makes the methodology powerful yet simple. This simplicity enable users from within a company to adopt and apply the methodology, a feature that gives the methodology considerable strength.

Application of the methodology in twenty-five organisations found it effective in providing insightful analysis and designing solutions that, when implemented, led to significant performance improvements. The methodology demonstrated a high level of generality, having been applied in organisations as diverse as multinational corporations and Small and Medium sized Enterprises, SMEs, across both manufacturing and service business sectors.

Application of the methodology uncovered the need to find better approaches to supply chain modelling and to managing programmes of performance improvement projects. In response, two new techniques were developed and validated. The first was the Time-based Supply Model. This device models the effectiveness of the processes that thread together supply networks using time as the key performance measure. The second was a structured idea-management system for performance improvement projects that uses a stage-gate approach to programme management. Combining this approach with the time-based methodology produced the Performance Improvement Model. This device provides a structure for managing the strategic direction and resource allocation of multiple performance improvement projects.

Portfolio Structure.

This Engineering Doctorate portfolio comprises the Executive Summary, Personal Profile and twenty-one submissions. The submissions are structured into five research phases, which group together individual submissions with common characteristics. This structure is shown below in Figure 1.

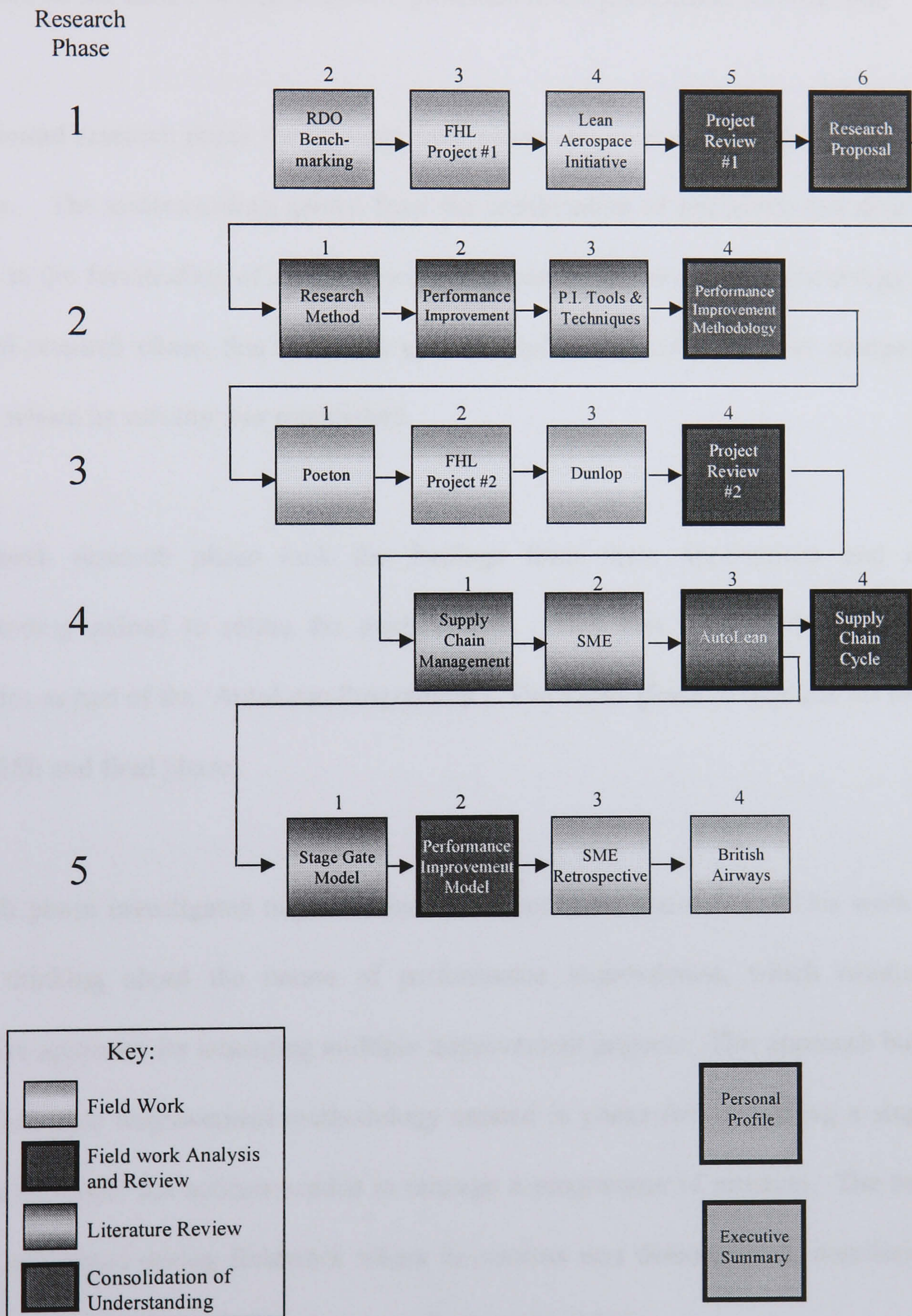


Figure 1. EngD. Portfolio Structure.

The **first** phase consisted of three projects based around Benchmarking, Time Compression and Lean Manufacturing respectively. These projects provided what could be termed a ‘research apprenticeship’, a period where research skills were acquired and developed. The knowledge and experience gained through these projects led to the development of hypotheses on the nature of improvement, grounded in the phenomena encountered.

In the **second** research phase the findings from phase one were considered against a body of literature. The understanding gained from the combination of fieldwork and desk research resulted in the formulation of a time-based performance improvement methodology. During the **third** research phase, this methodology was applied and tested in three company based projects where its validity was established.

The **fourth** research phase took the findings from these applications and used the understanding gained to refine the methodology. This was then applied in twenty-one companies as part of the ‘AutoLean Programme’. The fourth phase of research set the agenda for the fifth and final phase.

The **fifth** phase investigated major recommendations from phase four. This work inspired further thinking about the nature of performance improvement, which resulted in an innovative approach for managing multiple improvement projects. This approach builds upon the performance improvement methodology created in phase two by adding a stage – gate structure to model the actions needed to manage a programme of projects. The model was applied and tested during fieldwork where its success was demonstrated, conclusions were drawn and recommendations for further work were identified.

1 Using the Portfolio

This Engineering Doctorate portfolio of submissions is structured in a way that follows the chronology of the research. The sequence of the submissions generally corresponds with the development of the concepts and ideas that resulted from this work. It is therefore possible to gain an appreciation of the portfolio by reading it from beginning to end. However, given the volume of work, approximately 240,000 words, readers are recommended to take a selective approach to it.

Instead of treating the portfolio as a sequential narrative it is more appropriate to consider it in terms of a pyramid structure, as shown in Figure 2 overleaf. The pinnacle of the pyramid is this Executive Summary, which provides an overview of the body of work. From here readers can follow their interest in an aspect of the work to one of the review or analysis submissions that make up the first tier of the pyramid. These submissions provide either a review of fieldwork or consolidation of understanding derived from literature review. These documents also act as signposts to work contained in a second tier of submissions, where the reader can follow enquiries further.

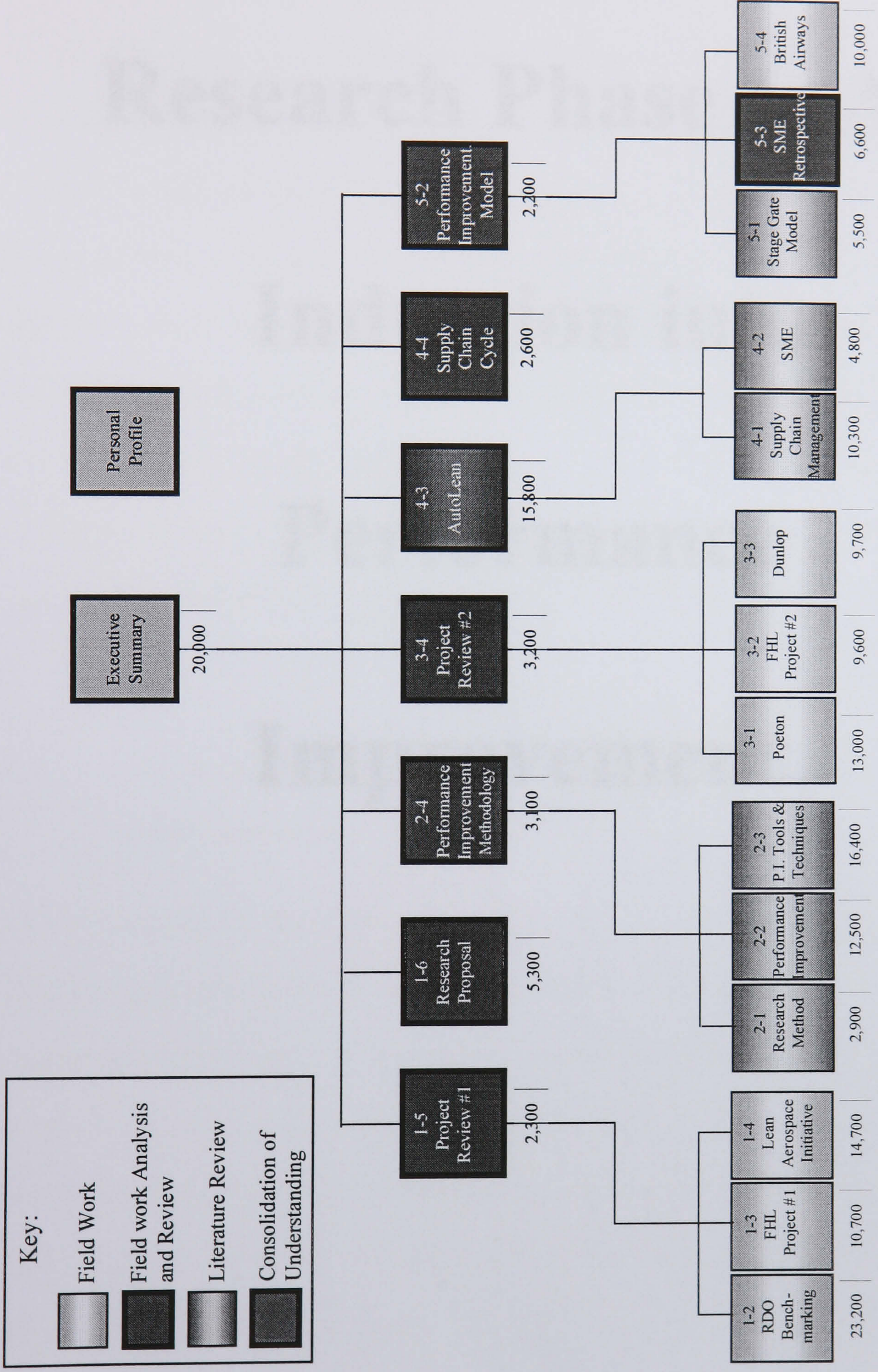


Figure 2. The Pyramid Structure of this EngD. Portfolio.

Research Phase 1: An Induction into Performance Improvement.

2 Initial Research.

The original objective of this programme of research was to develop and test a methodology for delivering performance improvements. The rationale for this was based on the observation that one of the reasons why firms fail to improve their performance is the lack of a mechanism they can readily apply. The focus for this interest in improvement lay in the application of Lean Thinking in small firms. This was fuelled by published accounts in the press and academic literature of the success achieved by the lean approach and a general awareness that small firms are economically significant and comprise a major proportion of most manufactured goods' supply chains but their efforts to improve are generally overlooked. Hence the specific aim was to create a methodology to support the application of Lean Thinking in small companies in order to resolve this situation.

2.1 Applicability of Lean Thinking to Performance Improvement

Given the considerable attention received by the 'lean' phenomenon in recent years it seemed appropriate to investigate its applicability to performance improvement. This author acquired a sound grounding in Lean Thinking whilst acting as Principal Researcher for the Lean Aerospace Initiative Risk Reduction Study, a detailed account of which is contained in Submission 1-4, Lean Aerospace Initiative, Risk Reduction Study. This was an investigation into the depth of understanding of Lean Thinking and the availability of case material on this subject in the UK aerospace industry.

The origins of lean manufacturing are credited as lying in Henry Ford's production system (Toyota, 1996). "Ford's principles in their purest forms are still valid and form the very basis of what we now know as the Toyota Production System (TPS)." (Krafcik, 1988).

Lean Thinking (Womack and Jones, 1996a) is the generic form of the Toyota Production System (Jones, Hines and Rich, 1997), representing a, "comprehensive business logic," (Womack and Jones, 1996b). However, Cox (1996) argues that the lean model is partial because it is based on automotive processes and operational techniques. Accordingly, such an approach, "cannot be used ... with equal success in all industrial and service sectors." (Cox, 1996).

Abo (1994) makes the point that lean production is a solution borne out of its Japanese settings. Although firms in other countries can adopt lean practices, "the outcome of these practices will unlikely resemble 'lean production' in Japan." (Abo, 1994). This author argues that successful transfer of benefits can only be achieved when the lean system is tailored to its new environment.

Despite a number of well-documented successes, 'lean' principles do not lend themselves to straightforward implementation (Lamming, 1996). Part of the problem lies in the absence of tools and techniques necessary to support the transformational process a company is required to undertake to become lean. Indeed, Womack and Jones found that most people trying to become lean were failing due to their inability to map the entire value stream for product families (Womack and Jones in Rother and Shook, 1998). Whilst a partial attempt could lead to isolated removal of waste, overall it failed to result in cost savings or deliver service and quality improvements to customers.

This lack of understanding provides a barrier to would-be practitioners, especially as application appears context specific. As a result, successful application of Lean Thinking is hindered by the lack of a well-defined and categorised tool kit to understand the value stream (Jones et al, 1997).

Conceptually the guiding philosophy of 'waste elimination' that underpins the Lean approach seems to have considerable merit. However, the ability to tailor the Lean system is beyond the means of most companies. Thus they will not achieve the advantages attributed to being 'Lean'. It is therefore considered that whilst the philosophy behind Lean Thinking should not be dismissed, alternative practices and techniques should be sought in order to deliver it. Consequentially, the focus of this research programme on Lean Thinking was dropped.

2.2 Applicability of Time-Based Approach to Performance Improvement

A more suitable approach to improvement was found to be Time-Based Thinking. The author acquired an understanding of this approach to improvement through undertaking a number of Time Compression projects. An account of one such project is contained in Submission 1-3, Fairey Hydraulics Non-Conformance Reporting Procedure, Time Compression Project. The time-based approach used during this project was found to have a number of characteristics that are valuable aids to performance improvement. These were:

- A time-based approach focuses on improving responsiveness;
- Using time as the key performance measure helps make the approach easy to apply
- It is a simple concept to understand;
- The development of the capability to undertake on-going improvement is helped by the ease with which the time-based approach is learnt.

-
- Not only is the time-based approach able to solve immediate problems, it can also improve medium term performance and develop capabilities that deliver long term benefits.

At this early stage in the research, these findings were noted but it was recognised that further work was required to validate them. This work was undertaken during the second phase of research.

In summary, the first phase of research involved working on a series of projects with a range of companies. Each project stood alone with different approaches used to work on different aspects of dissimilar organisations. Whilst there was little connectivity between the projects, they were all concerned with improving performance. At this early stage in the research this unfocussed approach unsurprisingly delivered little quantitative insight. It did however serve as a thorough and wide ranging general induction to performance improvement for the author. This resulted in a better understanding of performance improvement, the learning from which is consolidated into Submission 1-5, Project Review Number 1.

In light of this improved understanding the emphasis of the research changed from a focus on Lean Thinking to time-based thinking and its remit was broadened beyond an exclusive focus upon small companies. Instead, performance improvement was considered in general, irrespective of company size whilst maintaining the proviso that whatever improvement methodology was developed must be applicable to small companies.

In light of the experience and understanding gained during the fieldwork of this first phase of research, the objective for the research portfolio was redefined. This became:

The development of a time-based performance improvement methodology that possesses general applicability.

A full explanation of the thinking behind this objective is presented in Submission 1-6. Research Proposal.

3 Research Method.

Having gained an appreciation of performance improvement during the first phase of this research programme and committed to achieving a goal, it was necessary to develop a methodology that could be employed to deliver the objectives of the Engineering Doctorate. The research methodology chosen comprised a combination of a phenomenological approach, which was used to develop innovations, and an Action Science approach, which was used for their application and validation. This methodology is described in detail in Submission 2-1, Research Methodology, and in summary here.

Alternative approaches to research exist, spanning a range from positivist through to phenomenological. The factors that determine the appropriateness of a particular approach from amongst this range can be considered in terms of the three important environmental factors that influence research, namely.

- Researcher skills and style
- Organisation politics
- Organisational resources

(from, Easterby-Smith, Thorpe and Lowe, 1991)

In terms of researcher skills and style, this Research Engineer was keen to operate within engineering businesses in order to acquire the expert knowledge of specific engineering areas required to fulfil the competence requirements of the Engineering Doctorate. Operating across a supply chain and the ensuing web of organisational politics necessitates a system-wide view to be taken. In addition, working across supply chains, in a range of business environments meant that organisational resources would be variable and potentially severely limited.

Given the characteristics of the research environment described above, Evaluation Research was chosen as the initial research approach. It is an appropriate approach given that preliminary investigations indicated that the application of performance improvement was a poorly understood topic.

Given that the path of this research was difficult to chart in advance with certainty, the 'flexible approach' of Evaluation Research was used to give suppleness to the research (Thorpe, 1995). Consequentially, a broad interest was followed across a number of subject boundaries. This allowed theories to be built grounded in case studies that provided a wide perspective of the research area as was the case with Phase One of the research. Theory building from case studies in this way was appropriate, as existing perspectives on the subject of performance improvement seemed inadequate (Eisenhardt, 1989).

The research methodology took a phenomenological approach to developing innovations based on the use of 'grounded theory' - the discovery of theory from systematically obtained and analysed data. (Glaser and Strauss, 1967). "The grounded theory approach is a qualitative research method that uses a systematic set of procedures to develop an inductively derived grounded theory about a phenomenon." (Strauss and Corbin, 1990). In this approach, the starting point is not a theory. Instead the starting point is an area of study and what is relevant to the area is allowed to emerge. Thus the unfocussed work of Phase One provided an opportunity to explore the area of improvement, from which clarity was distilled in Phase Two.

In keeping with grounded theory, initial data was collected and preliminarily analysed in advance of consulting prior research literature. This approach was used to provide a fresh

perspective, independent of previous literature and as such, “is most appropriate in the early stages of research on a topic.” (Eisenhardt, 1989) In this approach, the literature researched over the course of the period of study was used to verify theories (Easterby-Smith, Thorpe and Lowe, 1991). This was the case with the literature reviewed during Phase Two. Later exploration of the literature also followed this approach.

Application of the innovations was undertaken with the aim of resolving problems in organisations and improving organisational performance. Undertaking the research programme in this way needs to involve a methodology that protects against the threats to validity inherent in process consulting. The principle threat to validity in this situation is the need to be seen by the host company to be successful, at the cost of rigorous application of the performance improvement methodology, i.e. fudging the research to get the ‘right’ result.

In order to address this threat to the research, a ‘clinical’ perspective on the Action Science approach was followed (Coghlan, 1994). This places emphasis on the usability of knowledge to help clients in organisations iterate through cycles of problem solving. Such was the case in the projects undertaken during Phases Three and Four. Following this approach, the researcher was involved with the client in a ‘helping role’. Schein (1969) defines the helping role as helping clients solve their own organisational problems. Involving clients in their own learning develops their capabilities better and also produces more valid data about how systems really work (Schein, 1969), two attributes at the heart of this research.

In order to mitigate the general limitations of action research, both quantitative and qualitative research was undertaken. Aspects of the research were designed to deliver quantitative data that allowed the effectiveness of the application of the innovations developed over the course of this research programme to be determined. In parallel, rigour was designed into the

qualitative aspects of the research methodology through the ongoing collation of information that would underpin the case studies. This was achieved by keeping a journal of findings from the fieldwork, generally in the form of meeting notes and progress reports. These records provide an audit trail against which findings and conclusions can be examined for consistency and to check the validity of the research. Designing this parallel approach into the research allows the richness of the qualitative data to be triangulated against the measures resulting for the quantitative investigation.

Research Phase 2: Design of a Performance Improvement Methodology.

4 Performance Improvement Structure.

The first phase of research found that companies were hindered in their efforts to improve performance by the lack of a methodology they could readily apply and follow. It was therefore concluded that an attempt to develop such a methodology should be undertaken. Work detailing the performance improvement methodology developed in response to this need is contained in Submission 2-2, Performance Improvement and Submission 2-3, Performance Improvement Techniques and Tools. The following section contains a summary and the conclusions of this work.

Performance improvement activities benefit from being undertaken in a structured manner with the support of techniques and tools. There are a large number of such techniques and tools, which possess a range of generality and differing levels of precision. Given this, it is useful to classify them in order to be able to select those best suited to a particular situation.

Kettinger, Teng and Guha (1997) classified improvement devices into three tiers of abstraction. A summary of these terms is presented below in Table 1.

Classification	Definition
Methodology	A collection of problem-solving methods governed by a set of principles and a common philosophy for solving targeted problems (Checkland, 1981)
Technique	A set of precisely described procedures for achieving a standard task. (Hackthorn and Karimi, 1988)
Tool	Instruments or tangible aids in performing a task (Hackthorn and Karimi, 1988)

Table 1. Classification of Performance Improvement Devices.
Source: Kettinger, Teng and Guha, 1997.

Authors from the Centre for Research in Innovation Management at the University of Brighton (CIRM, 1997) adopt an alternative two tier classification of improvement devices consisting of:

- A general approach to improvement
- Specific tools and techniques for dealing with specific problems.

Whilst the classification terminology of both groups of authors lack precision it is possible to identify commonality and divergence between them. Under their classification, the CIRM ‘general approach’ is the device that describes the overall structure for improvement activities. It is akin to Kettinger et al’s ‘Methodology’ in that it provides a framework to govern problem-solving methods. However it does not define the principles and common philosophy for solving problems included by Checkland (1981) in his definition.

Both sets of authors converge on the need for techniques and tools that provide described procedures and aids to undertake tasks and deal with problems. In their classification, Kettinger et al interpret a tool as being a particular software package that aids a specific task. CIRM do not distinguish between the terms although they imply that a technique is a higher level of abstraction than a tool and may be made up of a set of procedures or tasks.

Overall, Kettinger et al’s classification of improvement devices into three tiers of abstraction seems to be useful, however it seems more appropriate to consider the components of the ‘methodology’ classification, i.e. philosophy and principles, separately and the overlapping areas of techniques and tools together.

Therefore classification of performance improvement devices is taken as consisting of the following three tiers:

- Philosophy of Performance Improvement
- Principles of Performance Improvement
- Performance Improvement Techniques and Tools

These classifications are considered in more depth below.

4.1 *Philosophical issues of Performance Improvement.*

Some issues that guide performance improvement need to exist throughout the methodology. These are termed 'philosophical issues' as they denote much about how the methodology is applied. The three philosophical issues of performance improvement significant to this methodology are:

- Application of Time-based Thinking
- Employee Involvement.
- Appreciation of scope for variations on generic processes, procedures, tools and techniques.

These three issues are considered separately below.

4.1.1 Time-based Thinking

Manufacturing strategy literature identifies a number of dimensions on which firms compete. These include quality, cost and delivery at a traditional and low level of aggregation (Hill, 1993). From this strategic perspective, Porter suggests that a firm faces a choice of two generic strategies, either cost leadership or differentiation (Porter, 1980). Cost corresponds to cost leadership whilst quality and delivery, including speed, time and reliability, ally to differentiation. These factors are not mutually exclusive and important relationships exist between them.

The application of Time-based Thinking, where time is used as the key measure of system performance, encourages users to undertake actions that deliver improvements to both cost and quality. The same cannot be said of actions that lower cost and the secondary effects of

quality-led improvement initiatives do not inherently lead to time savings. (Schmenner, 1988)

The focus of Time-based Thinking lies in the ability to deliver to customers what they want, when they want it and thus create competitive advantage. Firms that take a systematic approach to becoming responsive can achieve a sustainable competitive advantage (Bower and Hout, 1988). The use of time as an explicit strategy has existed since the early 1980's, most notably when pioneered by Japanese motorcycle manufacturer Honda. Their response to a threat from Yamaha was a decisive series of new model introductions. The result was an emphatic victory based around their speed in new product introduction (Stalk and Hout, 1988).

The concept of responsiveness extends into manufacturing where, importantly from a customer perspective, the 'right' products are made available at the 'right' time. Toyota famously applied a time-based approach to their sale – manufacture - distribution cycle, cutting it from between four and six weeks in the late 1970's to eight days by 1987 (Stalk and Hout, 1988). This allowed customers to receive 'factory fresh' cars made to their requirements using the JIT approach. This negates the need for large levels of finished goods otherwise necessary to cover all the possible specification permutations.

Henry Ford, on whose work the Toyota Production System and thus Lean Thinking are based, was strongly influenced by time in the design of his production systems. He noted that the "time element in manufacturing stretches from the moment the raw material is separated from the earth to the moment when the finished product is delivered to the ultimate customer." (Ford, 1926) This resulted in remarkable cycle times. "Our production cycle is about eighty

hours from the mine to the finished machine in the freight car.” (Ford, 1926) Amongst these eighty hours, the time taken to assemble a car was just twenty-five minutes (Prioleau, 1913)

The strength of the time-based approach to competitiveness is that analysing process performance from a time-based perspective identifies waste in processes (Gregory and Rawling, 1997). Whilst taking time out of processes, firms also take out cost and improve quality. The reverse is not always true (Stalk and Hout, 1990). Reducing lead times speeds feedback and hence quality costs are reduced (Meyer, 1993). Shortened lead times in product development are achieved in part by more effective resource utilisation, rework elimination and a focus on only the necessary activities, thus leading to cost reductions (Smith and Reinertsen, 1991). In many ways this supports Benjamin Franklin’s eighteenth century adage that, “Time is money.” (Bryson, 1994).

Time-based Thinking proves to be easy to apply through the use of time as the key measure of process performance. Despite being a simple metric, time allows a rich understanding of the symptoms of poor performance and is effective in identifying and diagnosing each of Ohno’s seven forms of waste, the elimination of which underpins the lean approach. Its usefulness is based on the relative ease with which this understanding can be communicated to those involved in a process and would be affected by changes to it. As such, time has been described as, “the most useful diagnostic tool for processes.” (Stalk and Hout, 1990).

4.1.2 Employee Involvement.

Changes to business processes should consider the human aspects of the organisation. "Any strategic programme of radical transformation such as BPR should take account of the politics of the organisation and should not presume that an apolitical environment can be created by the application of technically rational management tools." (Taylor, 1995) Considering business processes as political systems in this way appears to offer an insight into their operation as organisational politics are considered to be, "an inevitable and central aspect of all decision making," (Coombs and Hull, 1995)

Therefore the most effective and long term approach to performance improvement appears to be based in improving the capability of people in operational roles to undertake improvement themselves. Accordingly, when developing a methodology to guide performance improvement through the analysis of processes and the development of appropriate solutions, a key goal is to provide an approach with supporting techniques and tools that users within the company can apply themselves. Achieving this goal strengthens the performance improvement efforts.

In order to undertake this they need to be able to follow generic improvement methodologies, understand how these can be adapted to meet changing circumstance and use a variety of tools and techniques to overcome the problems they will inevitably face. They should also have the ability to understand the experience of others in order to learn rapidly when faced with new problems. The utilisation of all capabilities possessed by employees, in a manner such as this, has been suggested as the key difference explaining the productivity improvements exhibited by Japanese manufacturers over their Western counterparts. (Oliver and Wilkinson, 1992).

4.1.3 Appreciation of scope for variations on generic processes, procedures, tools and techniques.

The need to appreciate the scope for variation in improvement devices (CIRM, 1997) is interpreted here as recognising that problem solving and improvement can be required in novel circumstances. In these instances prescribed responses may not be available so generic techniques and tools will need to be adapted in order to be effective. Such action will be aided by access to the experience of others.

The need for variation in improvement devices discredits the concept that there is one, 'right' approach to improvement. The uniqueness of each business environment has been shown to call for generic approaches to be tailored to match prevalent circumstances. For example, different organisations and industrial sectors place different emphasis on the various tools and techniques of BPR. (Grover and Malhotra, 1997). This appreciation of alternative approaches and the scope for variation within them extend to the choice and application of techniques and tools.

At a conceptual level, developing the mechanisms for organisational learning that develop general skills in improvement methods and tools seems to have value in supporting the appreciation of variation. Appreciation of the scope for variation in the methodology links closely with the accessibility of knowledge on what works / what does not, and the reasons why this is the case. Such learning can be considered as being made up of a number of levels of, "doing things in new ways" (Brown, 1996). The simplest approach to doing things in new ways is to improve activities using single loop learning, i.e. make them better in a regular and predictable manner within the confines of the established set of insights and principles (Argyris, 1982).

Whilst having the capability to undertake first order learning is valuable, having the capability to undertake second order learning is more effective. Second order learning underpins the ability of people to search for solutions not currently known. Such learning involves challenging the underlying rules and undertaking change in a different way. A more detailed account of single and double loop learning is contained in Submission 2-3, Performance Improvement Techniques and Tools, where they are discussed in the context of Kolb's Model of Experiential Learning (Kolb, 1984).

Capturing the learning when new approaches are discovered provides the mechanism that develops the general approach, techniques and tools over time. This is necessary in order to develop the methodology itself in response to changes in the business environment and to maintain its relevance and effectiveness.

4.2 Improvement Principles.

A set of principles for performance improvement were identified, as a result of the research undertaken during Phase Two. This work is presented in detail in Submission 2-2. Performance Improvement. In summary, the set of improvement principles used to guide the development of the Performance Improvement Methodology were:

- Improvement should be continuous
- Improvement efforts should be directed at business processes, the mechanisms for delivering value to customers.
- Improvement efforts should use a methodology consisting of a General Approach supported by a set of techniques and tools.
- The methodology should itself evolve over time
- Improvement should be viewed as a multidimensional activity requiring both radical improvements of core processes and incremental improvements in general.

These principles provided a base on which the performance improvement methodology was developed and guided the assembly of the set of techniques and tools presented in the following section.

4.3 Performance Improvement Techniques and Tools.

Amongst the approaches to performance improvement described in Submission 2-2. Performance Improvement, those associated with Business Process Reengineering. BPR, were concluded as being the most thorough and robust. BPR has an extensive literature base and a structure that spans the generic improvement cycle and takes an interorganisational approach to the context of improvement.

Amongst the plethora of BPR methodologies, the research contained in Submission 2-2 identified a strong and appropriate general approach in the 'Business Process Re-engineering Methodology for Small and Medium sized Manufacturing Enterprises' developed at the University of Plymouth (Smart, Maull, Childe, Bennett and Weaver, 1996). This approach was designed for use by academic and industrial groups wishing to develop a BPR methodology for SMEs

One of the main strengths of Smart et al's work was the provision of accompanying material that made its understanding comparatively easy. However, it was found that although this approach was generally strong it possessed a number of weaknesses. For example, only a top-level breakdown of the approach was provided, with little detail shown. The consequence of this was that the methodology provided an overview of the steps involved in undertaking BPR but did not do so in sufficient detail for it to be considered a prescriptive approach that will lead to success.

Overall, this methodology proved sufficient to be used as the basis from which to develop an appropriate general approach. To support this general approach a series of techniques were selected. This selection reflected the needs of SMEs and to support a time-based approach to

process improvement. The structure of the general approach to performance improvement and its relationship to the techniques and tools for taking a time-based approach are shown in Figure 3, overleaf, where an IDEF0 structural format has been used.

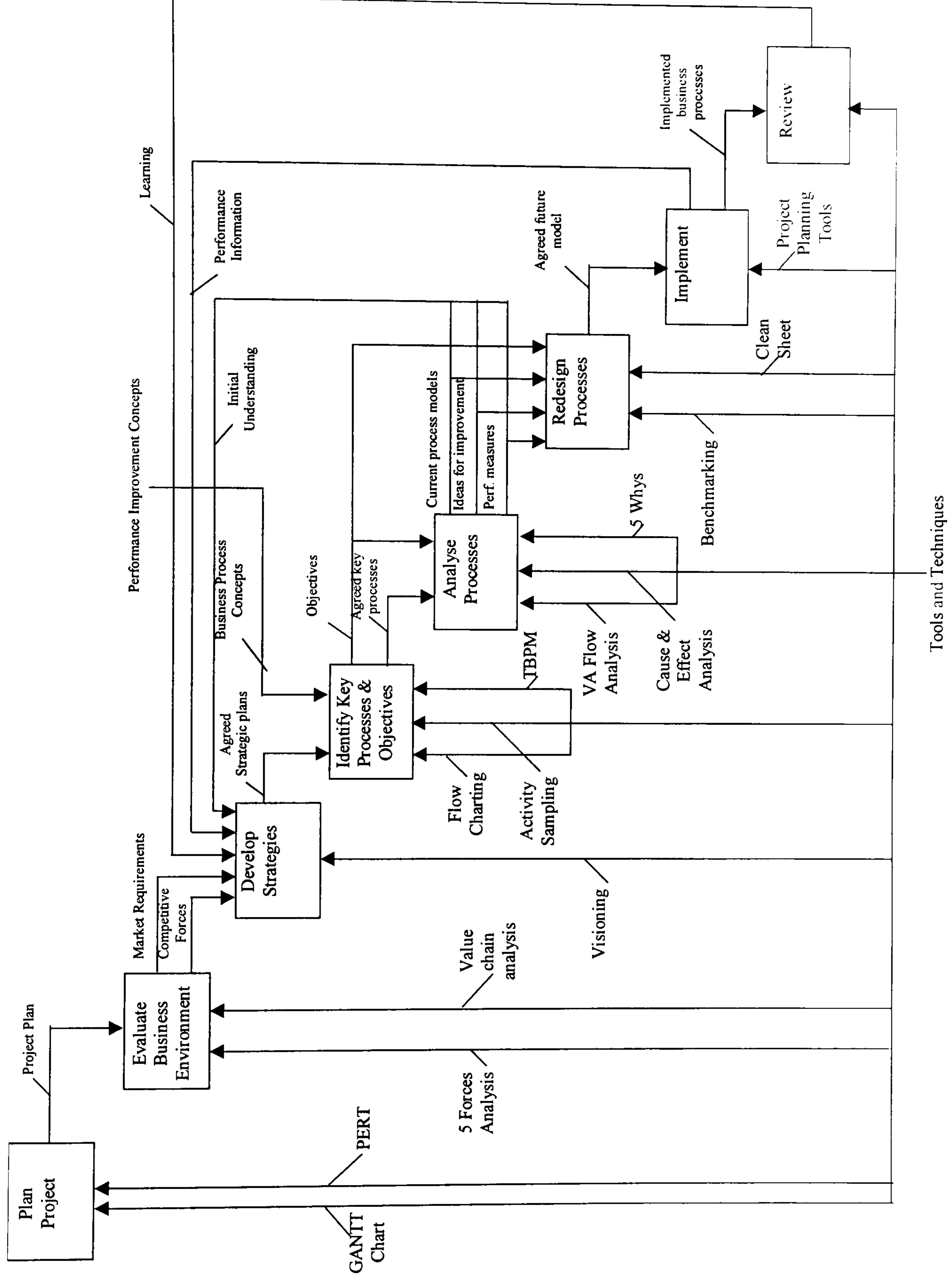


Figure 3. Performance Improvement Methodology General Approach.

The general approach shown in Figure 3 consists of eight, sequential steps. Each step is undertaken by using the supporting techniques and tools. The final step of the methodology, the Review, is used to consolidate learning acquired during a project. This learning provides the basis on which to launch further cycles of improvement.

The concepts on which this methodology is based are grounded in the understanding gained during fieldwork undertaken in Phase One of this research. Their development was guided by reviewing them against learning acquired during Phase Two. Verification of this work was explored during research undertaken during Phase Three. An account of that work is presented in the following section.

4.3.1 Scope for Variation Around the General Approach.

Whilst Figure 3 presents the general approach using an IDEF0 structural format, alternative representations exist for presenting and considering the general approach, such as by contextualising the stages of the approach against Kolb's Experiential Learning Cycle. The use of alternative representations for the general approach provides complementary understanding and demonstrate the need and benefits of for variation in the techniques and tools involved in process improvement, as presented above, in Section 4.2.1 of this dissertation, 'Appreciation of scope for variations on generic processes, procedures, tools and techniques.'

A full account of alternative representations of the general approach, including Kolb's Model of Experiential Learning and the IDEF formatted Business Process Reengineering approach, is presented in Submission 2-3, Performance Improvement Techniques and Tools.

Research Phase 3:

Application of the Time-

Based Performance

Improvement

Methodology

5 Introduction.

An appreciation of performance improvement was gained through fieldwork undertaken during the first phase of research. The second phase of research involved desk research where the time-based improvement methodology was developed. This third phase of research applied the methodology during three improvement projects, allowing its validity and effectiveness to be tested.

5.1 *Application of Methodology.*

This phase of fieldwork consisted of applying the performance improvement methodology during three projects. Two of the companies, A.T. Poeton & Son and FH Ltd. were SMEs and the third, Dunlop Tyres was a large division of a multinational company. This mix of project environments provided an opportunity to test the generality of the methodology and to explore commonality and difference in improvement projects between small and large companies.

The aim in all three projects was to follow the Action Science approach by applying the knowledge embodied in the performance improvement methodology to resolve problems in the companies and improve performance. The clinical perspective to this approach involved helping people in these companies to overcome problems themselves by developing their capability to use the devices that constitute the methodology.

Detailed reports on these three case studies are presented in the following submissions:

- Submission 3-1. A. T. Poeton Ltd. Time Compression Project.
- Submission 3-2. FH Ltd. Engineering Time Compression Project

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- Submission 3-3. Dunlop Tyres Ltd. Investigation of Sales and Distribution Operations.

The project at Poeton aimed to improve the responsiveness of the company's chrome plating operations. This brought together a group of production operators to learn and apply the improvement methodology to their work. The group was facilitated through the steps, where they examined the effectiveness of their production cell, identified waste and its causes then developed and implemented solutions that improved responsiveness.

The FHL project applied the methodology to the design function in this aerospace actuation system manufacturer. This brought together people from across the design function into a group where they were facilitated through the methodology.

The Dunlop project involved working within a specialist performance improvement team that applied the methodology to the process of fulfilling aftermarket customer orders.

5.2 Methodology Effectiveness.

The effectiveness of the methodology was assessed in terms of

- Effect on company performance
- Project costs
- Effect on performance improvement capabilities

5.2.1 Effect on Company Performance.

The returns from a company's investment in a project are time dependent. Some returns will be experienced in the short / medium term whilst others will not be realised until the medium / long term. Despite this, the return to a company against which it should consider the

effectiveness of a project was taken as being the achievement of specific deliverables set out and agreed in their project proposal. Typically this was the presentation of a report containing a set of recommendations for change that, when implemented, would lead to performance improvement.

Against this measure, all three projects delivered their objectives. However, only at Poeton were these recommendations implemented and business practices changed. In this instance, performance improvements were achieved in line with the assessment made in the report.

Recommendations were not adopted in the other two cases due to influences beyond the scope of the projects. However, the recommendations and the analysis that led to them were considered by the companies to be sound.

5.2.1.1 Individual Project Results

The Poeton project resulted in the acceptance of the report of findings by the company's Senior Management Committee followed by the implementation of the recommendations contained within. This led to both a reduction in the lead time for turning around chromed items by over 50% from 8 days to 3.7 days and increased reliability of achieving delivery targets from 50% to 85%. These improvements occurred over a one year period whilst the volume of work increased by 20% and with a constant level of manning.

At FHL, the presentation of a report by the project team provided detailed findings and recommendations for improvements to a senior management team including the Engineering and Managing Directors. This investigation into the company's engineering activities proved to be thorough, resulting in a number of fundamental difficulties with the product introduction

process being identified and the benefits of implementing the proposed improvements quantified.

Considering the traditional 'engineering' function as a new product development process for the first time enabled poor performance including lead-time delays, quality risks and wasted resource to be identified. The performance of current activities was measured using time as the key metric, allowing the incidence of poor performance to be quantified. The causes of wasted time were explored and root causes identified. Examples of the causes were sequentially organised processes and poor use of bottleneck resources. A novel, process-orientated approach to engineering activities was developed including the introduction of parallel operations and focused training to increase capacity at bottlenecks.

Although the senior managers felt that the approach taken and conclusions reached were sound, they were unwilling to support the implementation of the proposed solutions. A subsequent project review confirmed that no changes to operational practices had been implemented and that the poor performance identified earlier still occurred. Given that the solutions to the problems identified were considered reasonable and within the capability of the firm to implement, this suggests the root causes of poor performance lay not in the Engineering process or operations but elsewhere beyond the scope of the project.

The project undertaken at Dunlop Tyres delivered its objectives when a presentation was made to a panel of directors and a report issued on the analysis of sales and distribution operations. Having documented the process for the first time, an analysis from a process perspective revealed opportunities to improve the key performance characteristics identified during the project as being valued by customers. Specific recommendations were developed together with an action plan for their implementation. These have not been implemented due to the merger between Dunlop's parent company Sumitomo Rubber Industries and Goodyear

Tires. This announcement coincided with the day the report of findings was delivered to Dunlop's senior managers. Given the tyre industry's excess of production capacity it is likely that the two companies will consolidate their businesses and close a number of plants. With Goodyear being the senior partner in Europe, closure of Dunlop facilities is likely. Understandably, the senior management team at Dunlop has been more concerned with this immediate issue than with implementing performance improvements.

5.2.2 Costs

All three projects were completed within the allotted time-scales and budgets. The time spent on these projects by operations teams and senior management and the consulting fees levied on the companies were substantially less than comparable, previous projects. Where improvements were implemented, there was a shorter time to experience benefit from the changes and the ratio of project cost to performance improvement was improved.

The 'Time Compression' projects at Poeton and FHL took six sessions, each of less than three hours. These were undertaken on a one per week basis, giving a project lead-time of six weeks. Previous time compression projects typically took twelve sessions spread over three months. These often included workshops of one or more days with overnight stays incurred by project team members. Accordingly, costs to the company in terms of facilitation fees paid to Warwick University, the cost of the time spent by company staff on the projects and associated expenses were significantly lower on the projects undertaken using the performance improvement methodology. An estimate of the savings that result from using the methodology is that costs are reduced by between one-half and two-thirds from their former level.

Whilst the Dunlop project was less structured than the other two projects, it was undertaken in line with its allotted resource. Through adapting the general approach, teamworking and process thinking were achieved amongst senior managers whilst minimising time demands on them. This variation of the methodology delivered substantial savings in the effort required to generate recommendations.

5.2.3 Effect on capabilities

Post project reviews were undertaken at all three companies to assess whether team members involved in the improvement projects were able to demonstrate subsequent applications of the skills and techniques that were introduced. This was found to be the case at both Poeton and Dunlop but not at FHL.

At Poeton, senior managers described the project as being a landmark in the company's efforts to improve performance. Despite previous attempts, this had been the first time shop floor staff had contributed to planned improvements. Harnessing their efforts was the major factor that had led to the significant and on-going improvements in performance. Ownership of problems that result in poor performance has been established within the shop floor team that was involved in the project. Where team members have undertaken subsequent improvements they have been able to use the tools they were trained to apply. This effort has further improved their knowledge of the tools and their capability to undertake ongoing improvements.

At FHL, team members were instructed in the general approach to process improvement and the tools that support it. To date, participants have not been involved in further projects and have failed to exploit the opportunity of using their capabilities to better deliver the new products that are critical to the future commercial success of the company.

At Dunlop, the lack of application of process thinking suggests that little learning was gained by the company. This is understandable given the position the company finds itself in. On a positive note, the core team of staff involved in the improvement project has been able to apply the improvement methodology in subsequent projects demonstrating that their improvement capabilities were enhanced during the project.

6 Discussion

The performance improvement methodology was followed in three different projects. Each was an example of undertaking a structured improvement project in an environment where this had not been achieved before. Using an approach consisting of a series of workshops, each with specific objectives provided a focus for the team and gave the impetus that helped them completed each one within a challenging time scale.

Applying the methodology in the dissimilar circumstances of the three projects involved varying the general approach and the use of the tools and techniques. Differences between the Poeton and FHL projects were minimal whilst they were more significant at Dunlop. In its original form the demands on the senior managers at Dunlop of following the methodology would have been too great in terms of time and effort. Instead, a way was found to involve them and gain their commitment whilst reducing the amount of time they had to spend on the project. The process owners, those people who undertake the tasks along the process, were used to provide understanding of the process whilst senior managers used this understanding of the current process to help them appreciate the need to apply a process-based approach to the operations. Only when current operations were understood could these managers enter into meaningful strategic thinking. The ideas and suggestions of process owners supported this thinking, again demonstrating the value of their contribution.

Considering the techniques and tools employed, process mapping and time-based analysis helped all three companies take a process-orientated perspective of their operations that quantified current performance and illustrated the need to change. High level flowcharts prepared using simple, common nomenclature presented information in an accessible manner,

allowing the process to be understood with comparative ease. This common understanding of the critical requirements formed the basis from which the processes were redesigned.

The need to improve responsiveness to the customer was a key reason for undertaking these projects, in addition to the general need to reduce cost. The removal of all types of wasted time was a prime objective in all three projects. Time-based Process Mapping proved valuable in representing the incidence of wasted time. It therefore helped focus the project teams attentions on resolving the causes of this waste.

7 Conclusions.

The performance improvement methodology proved to be successful in delivering the objectives of all three projects. The structure of having a general approach supported by tools and techniques enabled improvements to be identified, although they were implemented in only one of the three cases.

In instances where a project team was faced by context specific difficulties then additional tools were incorporated into the general approach to overcome them. This finding served to demonstrate that whilst a core group of tools existed that were used in all the projects there was the need for a supporting group of others that would only be employed when particular issues arise.

The inclusion of supporting tools where circumstances demanded it and the omission of core tools where they were unnecessary gave flexibility to the methodology. This was also the case when the structure of the general approach was changed. The difficulty associated with this flexibility is the understanding of where it is appropriate and the rules that guide it. These issues are not clear and were tackled over the three projects on a case by case basis. This suggests that experience of applying the methodology is beneficial in appreciating both flexibility in the methodology and the decisions that guide the application of tools. These conclusions concur with findings by Bessant et al (CIRM, 1997) that key techniques that support continuous improvement appear to include an appreciation of scope for variations on generic processes, procedures, tools and techniques.

8 Recommendations for Further Work.

Further application of the methodology was needed beyond the research undertaken during Phase Three to understand generic benefits of the methodology, identify adaptability issues, clarify the boundaries of the scope for variation and qualify limitations.

A further phase of research was also required to explore an observation made whilst undertaking this fieldwork. During all three projects, investigations into problems identified a very large number of likely causes. It was noted that the high numbers of improvement opportunities uncovered proved difficult to manage. Therefore a solution to this problem was required.

Research Phase 4:

Application of Time-Based

Performance

Improvement in

Automotive SMEs

9 Introduction

The performance improvement methodology was employed as the basis for an approach to guide the introduction of Internet-based Information and Communication Technology, ICT, into the business processes of automotive component SMEs based in the West Midlands region of England. This section of the Executive Summary presents an overview of this research, which is compiled from work contained in the following portfolio submissions:

Submission 4-1, Supply Chains, provides a background of understanding on the contribution of suppliers to the development and supply of products and services. This explores supply chain frameworks, models, business drivers and management practices.

Submission 4-2, Small and Medium Enterprises, defines and quantifies the importance of SMEs and identifies their characteristics. A review is also undertaken of the automotive components industry and companies in the West Midlands region. The submission draws these strands together and concludes with an assessment of West Midlands automotive component manufacturing SMEs.

Submission 4-3, AutoLean, contains a literature review of Internet-based Information and Communication Technology and its use in improving supply chain performance. This submission also provides a full account of the application of the performance improvement methodology to guide the implementation of Internet-based ICT to improve SME performance.

9.1 West Midlands Automotive Components Industry.

Since the Industrial Revolution, the West Midlands region of England has had a strong manufacturing base. Despite recent deindustrialisation (Economist, 1998), the region relies on manufacturing for a third more of its wealth and employment than is typical in the UK (De Propriis and Oughton, 1997). The automotive component sector is especially strong, with the West Midlands significant from both UK and EU perspectives of the automotive industry with 17% of the UK's first tier purchase sourced in the region (KPMG, 1998).

The performance of automotive component manufacturers in the West Midlands is considered by many of their customers to be below increasingly stringent requirements. Consequentially a third of current contracts are in danger of being resourced outside the region (KPMG, 1998). In addition, OEM and major first tier customers are also demanding further cost cuts and improvements in supply responsiveness. Accordingly, there is a need to improve competitiveness.

A significant number of West Midlands automotive component suppliers are small businesses. Whilst figures are not exact, they are believed to be consistent with UK demographics for small and medium enterprises, SMEs, which make up 99% of businesses and provide 67% of employment (Storey, 1994). These small businesses make up a significant proportion of the automotive supply chain. Traditionally treated by many customers as mere suppliers of components at the lowest price, they are gradually becoming recognised as having expertise. For example, their contribution to new product design can significantly reduce costs and improve quality (Goffin et al, 1997).

9.2 Introduction of Internet-based ICT into SMEs.

The use of Information and Communication Technology, ICT, has been found to improve business competitiveness, with the Internet providing the opportunity for SMEs to compete on equal terms with larger organisations (Mellor, 1999). In particular, e-mail and the World Wide Web present opportunities for SMEs to harness the benefits of ICT in an affordable, simple way.

Small UK businesses generally lag their larger counterparts in the use of the Internet. In terms of the entry level and foundation applications of the Internet, i.e. e-mail and a web site, the difference is quite significant. UK SMEs are around half as likely as large companies to use e-mail, whilst for micro companies the figure is even smaller. The number of businesses with web sites also followed this trend, with company size a major characteristic in determining the use of this technology. Specifically, smaller companies were found to lag behind their larger counterparts in the uptake of Internet ICT in the automotive components sector (Spectrum, 1997).

9.3 *Issues preventing Internet adoption.*

The adoption of ICT by SMEs to allow them to achieve inter-organisational exploitation of the Internet has been found to be prevented by a number of major issues (Spectrum, 1997).

These consist of the:

- Lack of understanding of the opportunities available to small businesses;
- Lack of understanding on how to implement these techniques;
- Lack of skills amongst the workforce to use them;
- Price of the technology
- Lack of willingness to dedicate time and resource to resolving their lack of understanding and skills.

The lack of understanding of the need to adopt innovations, such as ICT, prevents SMEs using them to overcome existing performance gaps or exploit new opportunities (Zmud, 1984). The lack of understanding on how to implement and then use ICT applications prevents the accomplishment of the strategic goals of efficiency, effectiveness and innovation (Feher and Towell, 1997) which denies SMEs this particular opportunity to improve competitiveness.

10 Methodology.

A programme of assistance was designed to respond to SME business drivers whilst overcoming the issues that prevent Internet adoption.

10.1 *SME Support Package*

The basis of the package of support to each SME was the use of European Regional Development Funding to pay for the supply, installation and support of a turnkey system for external Internet connection, supported by business analysis undertaken to identify immediate opportunities for inter-organisational communication. Together this programme provided a starting point for ICT adoption by a firm consistent with Poon and Swattmans' model for implementing Internet ICT in small businesses (Poon and Swattman, 1997). These authors postulate that the entry point for SMEs to use the Internet is for them to start with the inter-organisational dimension only. Integration with their business processes occurs subsequently, with full Internet-to-internal process integration only achieved following significant organisational process adjustment within a company and also across the business sector it operates in.

10.1.1 ICT Package

The ICT aspect of the project involved the specification, sourcing and installation on-site of a PC based system capable of connecting a company, with no existing hardware or software resources, to the Internet. A training programme was also designed to enable SME personnel to make the best use of these emerging technologies, which assumed no prior experience. This training comprised hands-on exercises with supporting literature designed to take account of the needs of SMEs. Newby (1998), Gibb (1998) and Garawan and O’Cunneide (1994) identified these needs as:

- Training presented in an acceptable way;
- Minimised time needed to undertake training;
- Material and approaches suited to small firms with minimum jargon;
- Publications and guides presented as part of a process of personal discussion and dialogue;
- Training delivered by personnel with special skills enabling them to interact with the SMEs productively.

Each company had a web presence established through the provision of an account with an Internet Service Provider, registration of a suitable domain name and the design and hosting of a web site. Support of the ICT package was provided over the first year of the project via an e-mail and telephone helpdesk with on-site visits undertaken when required.

10.1.2 Business Analysis Package

SMEs want solutions to practical problems, “smaller enterprises with short term horizons and limited resources need immediate solutions to immediate problems,” (Storey, 1999). In order to identify opportunities for a company to improve its performance through the application of Internet ICT, each business was analysed. This involved the investigation of their three key business activities, namely how they won new business, how new products were developed to satisfy orders for the first time and how new orders for existing products to existing customers were satisfied. Each of these three activities involved people carrying out collaborative activities in order to achieve business objectives. These characteristics identify them as being processes (Ould, 1990).

The mapping, measurement and analysis of these processes followed a time-based approach given the importance of responsiveness to SMEs and the pressure from customers to reduce lead times. The use of Time-based Process Mapping, TBPM, allows time to be shown in a graphical format, illustrating where time is wasted in a process. An example of a Time based Process Map is shown below in Figure 4.

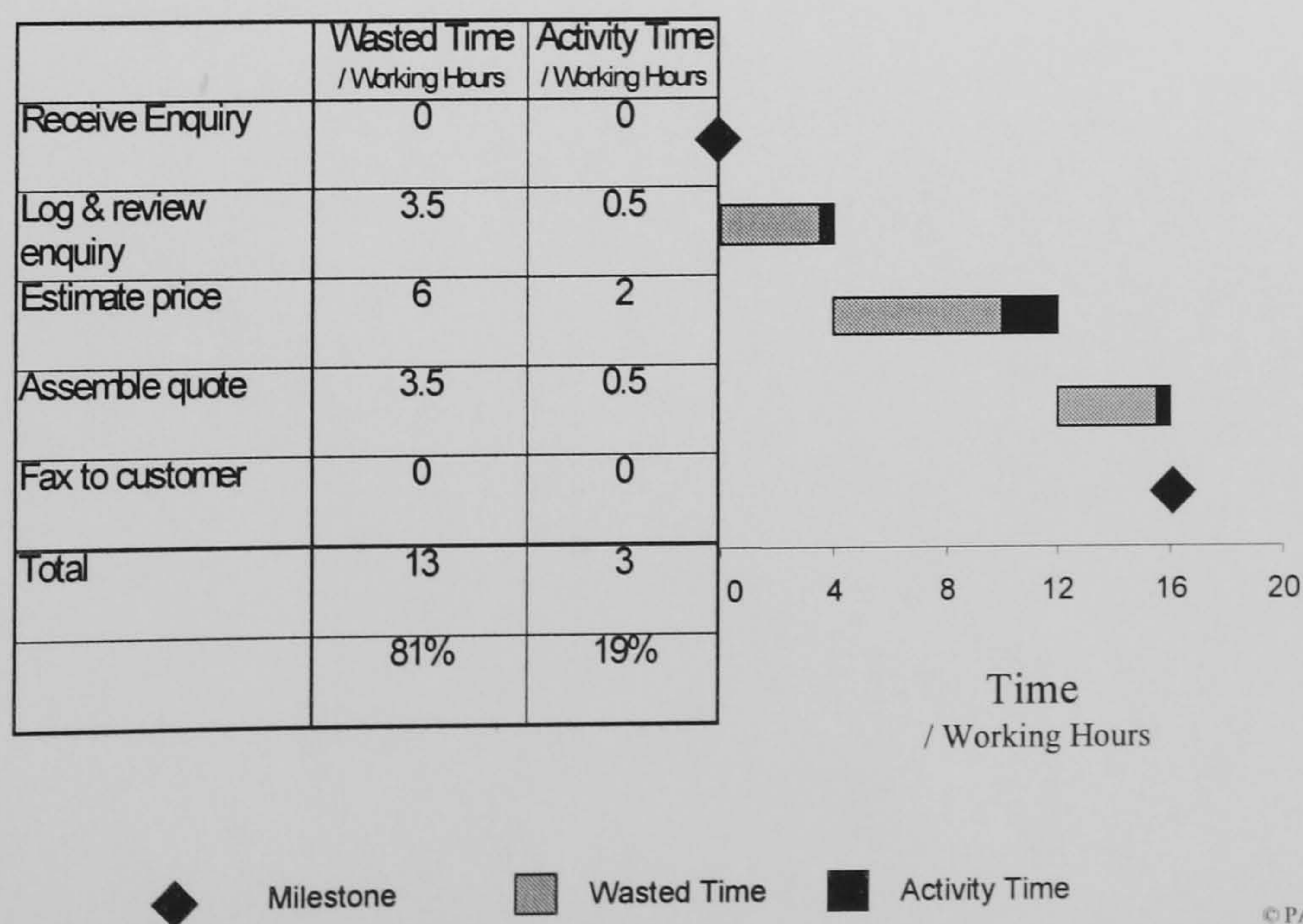


Figure 4. The Time Based Process Map of a Quotation Process.

In this simple process, it can be seen from the TBPM that it takes this company sixteen working hours, two working days, to respond to an enquiry and deliver a quote. Within this two day lead-time, three hours are spent working on the quote whilst the other thirteen hours pass without any work being done on it.

Using TBPM process maps during the discussion of findings with companies proved useful in conveying understanding. This led to the identification of immediate opportunities where Internet capabilities could be utilised to deliver performance improvements. It also identified opportunities for capability building that would lead to further benefits.

10.1.3 Funding Package.

In order to fund the PC system, training and consultancy, money and time invested by companies in their projects attracted matched funding from the European Regional Development Fund. This was available to support eligible companies that satisfied the EU definition of an SME within the West Midlands 'Objective Two' region (Government Office for the West Midlands, 1996).

10.2 *Implementation.*

The programme of assistance was undertaken with twenty-one companies. All had their turnkey ICT systems installed, undertook the training and had their business processes analysed. This work took a total of three days, which were scheduled over a two-week period.

10.3 Programme Review.

In order to assess the effectiveness of the programme of assistance, data was collected against the immediate ability of company managers to use the consultancy advice they received and then the subsequent level of Internet ICT use in the company one year after implementation.

In summary, the companies found the methodology helped them consider their businesses from a process perspective. This provided these companies with new understanding of how their business operated. In general, this understanding provided them with the direction on how to use their newly acquired Internet capabilities

A measure of how the companies perceive the value of Internet ICT was taken as being their ongoing level of use. Accordingly, usage was measured approximately a year after implementation to allow for the novelty of the project to wear off and a steady state level of use to be established.

This review found that ninety percent of companies, nineteen of the twenty-one, continued to use e-mail. Six of the companies had increased the number of people who used e-mail by more than 20% whilst a similar number reduced the number who used e-mail by more than 20%.

Use of the World Wide Web by company staff was found to have reduced significantly. In six cases usage ceased altogether whilst in most of the other companies it reduced by more than 20%. The number of people who used the web increased in only one company. A positive perspective on these results is that after a year, over seventy percent of companies still had employees who used the World Wide Web.

10.4 Implications: Theory

The package of support developed to overcome the constraints faced by SMEs in their adoption of ICT demonstrated success in being able to inform the companies and sustain use amongst a significant number of them. This implies a number of conclusions. Firstly, the set of major factors hindering adoption of ICT amongst SMEs seem to have been correctly identified. Having overcome these, most companies were able to use the Internet. Secondly, the provision of a package including a turnkey system, training, business consultancy and funding appears to be a successful mechanism for overcoming these constraints.

In terms of the approach taken to apply the ICT adoption package, support was found for the model proposed by Poon and Swattman (1997). Their theory that ICT adoption by SMEs begins with external communication finds support in these results. However, these findings do not negate Venkatraman's (1994) alternative hypothesis acknowledged by Poon and Swattman where firms' progress towards communication with other organisations having first utilised the technology to communicate internally. However, it seems likely that SMEs will find less benefit through internal communication than their large counterparts given their typical characteristics of closer physical collocation of staff on single sites and greater personal familiarity amongst them. Benefits from implementing intra-firm electronic communication will also be hampered by lower skill levels and familiarity with computer packages and the lower density of computer equipment and therefore access in smaller businesses. Given these factors, the set up of an internal network will be relatively difficult to justify in a small firm.

10.5 Implications: Practice

Companies found business process understanding gained through process mapping and analysis led them to understand the opportunities available to them through using ICT. This analysis also led to a more thorough appreciation of business processes in general which has the potential to lead to further benefits in addition to those gained through the adoption of ICT.

The lack of understanding in the small businesses on how to implement and use ICT was overcome by the use of turnkey systems. The lack of skills amongst the workforce to use them was resolved by following up the implementation with a programme of training and provision of ongoing, helpdesk support.

The combined programme of support to the companies of process analysis and system implementation allowed the firms' newly acquired Internet capability to be targeted and applied to specific tasks that deliver immediate benefits to the firm. This entrenched its use and demonstrated the value of these practices as useful business tools.

The cost to participating companies of implementing the ICT system, training and business analysis package was minimised through subsidisation using ERDF funding. The effect of this was to minimise the return needed for the small business to justify the project. This allowed them to overcome short-term financial considerations resulting in the companies now being in a position to accrue the on-going benefits of ICT.

10.6 Methodology Conclusions.

The provision of a holistic programme of a PC preloaded with commercially available software, staff training and a business process analysis package enabled SMEs to exploit Internet ICT in a structured manner. Whilst small firms can readily purchase the ICT package from most retailers, the supporting business analysis proved essential in providing the guidance for how the technologies could be integrated into business processes. This allowed the value of Internet-based ICT to be demonstrated by identifying how it could be used to deliver business benefits.

Implementing this package in twenty-one firms demonstrated that it provided a significant number of them with the capability and understanding to exploit Internet-based ICT. The effect of this implementation was that ninety percent of companies, nineteen of the twenty-one, maintained and were using their capability to exploit inter-organisational, Internet-based ICT.

11 The Effect of ICT on Business Performance.

Whilst Poon and Swattman argue that measures of specific benefits resulting from the use of ICT is inappropriate (Poon and Swattman, 1996), the aim of this research programme was to improve business performance. In order to determine the effect on company performance from adopting Internet-based ICT two measures were taken.

- The effect of the communication technologies on the number of orders or contracts the companies won.
- The effect on business performance.

11.1.1 Effect on Orders / Contracts.

Executives at the companies were asked to determine what effect the adoption of Internet ICT had on their ability to retain or win orders or contracts. Around half the companies reported that they retained business they would have otherwise lost or won new business as a direct result of the adoption of the new communication technologies. There was no detrimental effect to the number of orders won by the remaining companies.

11.1.2 Effect on Business Performance.

Overall, a little over three-quarters of the firms could demonstrate quantifiable performance improvements as a result of adopting ICT. These changes were considered as having occurred if evidence was found of any type of performance change in any one of the three core business processes.

Those firms that demonstrated performance improvements were investigated further to quantify the types of performance improvements they were experiencing. All the companies whose performance improved were able to offer examples of where their cost and lead time had improved and their company image had improved. In some instances reduction in lead-time had led to the cost reduction. However, the majority of companies were able to demonstrate cost reduction through additional mechanisms as well. Improvements in delivery dependability and higher quality were also found to be achieved, although less often and to a lower magnitude.

12 Discussion of Results.

Examining the results of the investigation into the effect of ICT adoption on business performance, a wide variation in the effect on performance was identified. Whilst no firm demonstrated a decline in performance, five firms demonstrated no change in performance. Amongst the sixteen firms where performance improved the level of improvement varied in rating between 'minor' and 'substantial'.

In an effort to understand the factors that influenced how companies employed their capabilities and explain the mechanisms behind the variation observed, extreme cases of change were examined. These were the cases where strong improvements were achieved and the instances where no change occurred.

12.1.1 Companies with greatest improvement to practices and performance

Examining the three firms that demonstrated the most substantial performance improvement, a number of common characteristics were identified. These were:

- Their customers were demanding ICT use.
- A number of customers possessed Internet Capability
- Senior managers were enthusiastic for ICT adoption
- The companies already possessed computer aided design and production technology

12.1.2 Companies with least improvement to practices and performance

A group of three companies that achieved no benefits from the programme was examined to identify common characteristics. Overall, these companies possessed few common attributes. The reasons why they had not adopted Internet ICT and had not benefited from them were very context specific, including:

- Company up for sale, therefore the owner was reluctant to invest money.
- Customers not demanding or interested in Internet ICT.
- Senior management concentrating on other business improvement activities.
- Lack of competence in IT for manufacture, project management and a poor appreciation of the strategic use of electronic communication and data sharing.

These observations suggest that the mechanism by which companies fail to improve their performance involve:

- Individual detrimental factors.
- Combinations of detrimental factors.
- Absence of supporting factors.

12.2 Correlating practice adoption with performance changes.

A phenomena observed during the course of the programme was that those companies that exploited their ICT capabilities more and were able to adopt advanced communication practices seemed to experience higher levels of benefits. Hypothesising that this was indeed the case, the levels of practices adopted and performance improvements achieved were examined for each company to determine whether there was a correlation.

Data collated from the companies on the extent of their practice adoption and performance improvements were indexed. A plot of the two indexed scores for each company is shown below in Figure 5.

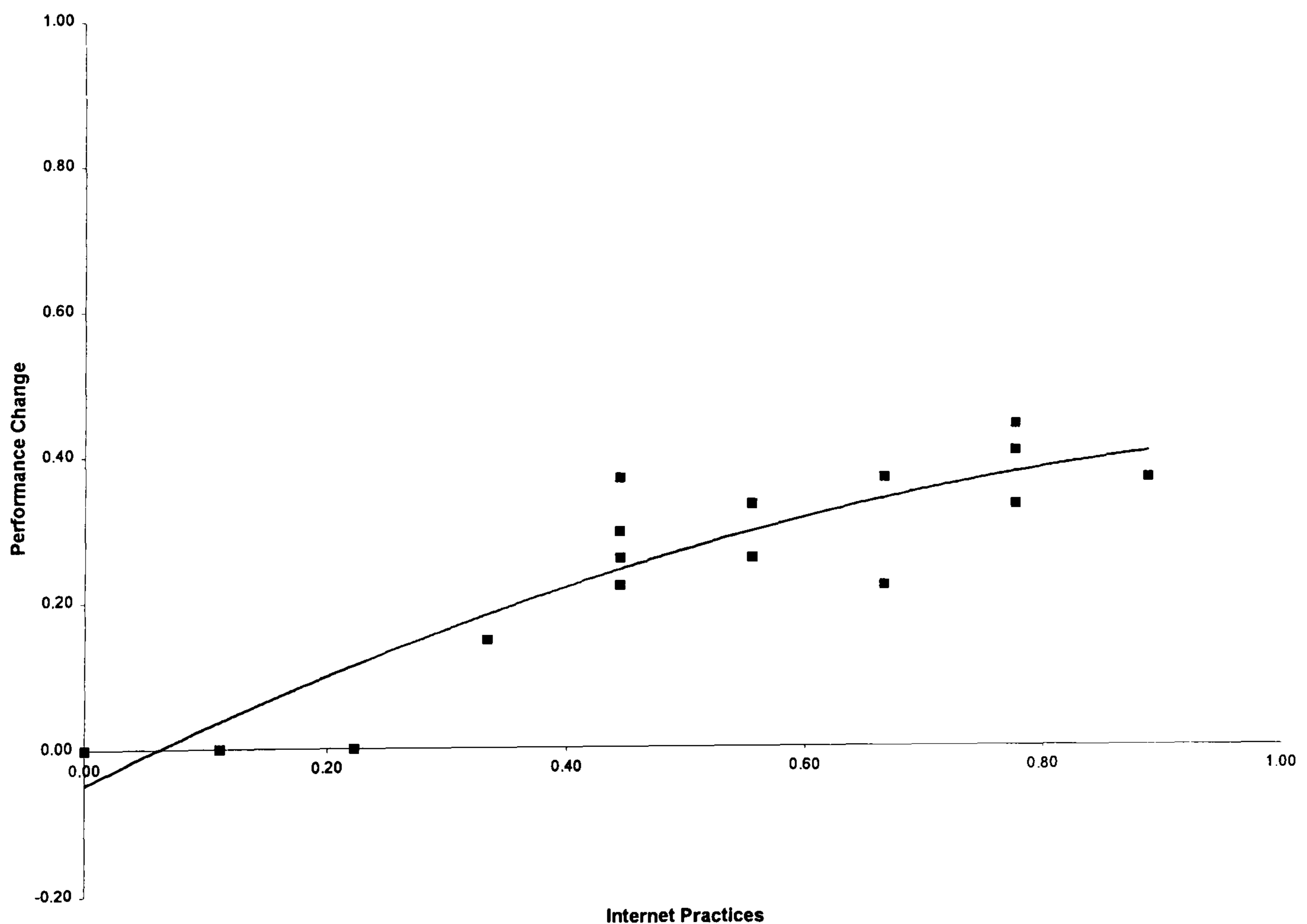


Figure 5. A plot of Internet practice adoption against resultant performance change

The plot of the level of Internet practice adoption against the resultant change in performance indicates that higher levels of adoption of the practices deliver larger improvements in business performance.

12.2.1 Discussion

Those firms that adopted and applied their Internet capabilities to the greatest extent tended to experience the highest levels of performance improvement. In a number of cases adoption and application of ICT generated significant improvements in competitiveness, securing jobs and winning new business. These dramatic changes occurred in a time scale of less than one year.

These findings should be considered in light of a number of areas where understanding still needs to be developed. Summarising the work in Submission 4-3, AutoLean, there were:

- The number and choice of performance criteria against which change was assessed was well grounded, however the scoring scale attributed to them was arbitrary.
- Difficulties exist in interpreting results due to interrelations between scoring criteria. The multiplier effects between these relationships have not been fully defined.

One of the effects of this lack of clarity is the observation that even where companies extensively implemented the Internet practices and exploited them to a high degree their performance improvements appear relatively low. In the study, the maximum score achieved on the performance index was 0.44, meaning that 44% of the total anticipated benefits were achieved. This situation can be interpreted in a number of ways:

-
- The scales on the two axis of the graph in Figure 5 are misaligned due to inappropriate or overly generalised performance measures, as described above.
 - There is a significant delay between the adoption of ICT and the resulting tangible benefits. This would mean that the full extent of the anticipated benefits are yet to unfold.
 - The research described above was only able to identify the means by which companies achieve the first stage of Poon and Swattman's 'Three Stages of Internet Integration in SMEs', i.e. inter-organisational exploitation. Hence even the most advanced companies involved in AutoLean have only completed the first stage and therefore have two further stages to undertake before they can achieve 100% of the theorised performance improvements. Adopting practices that integrate their inter-organisational Internet capabilities with internal applications might then enable the companies to achieve the improvements that currently elude them.

13 Conclusions

The AutoLean programme took as its basis the time-based performance improvement methodology. This was applied to guide the implementation of ICT in SMEs. This resulted in nineteen of the twenty-one companies involved in the study still using the technology a year after its installation. Consequentially, sixteen of the twenty-one demonstrated lead-time and cost reductions and improvement in company image. Ten of the companies, forty-eight percent, found they either won new business or retained business they otherwise would have lost as a result of their use of ICT.

These returns have been shown to be available from a relatively low level of investment and often served to leverage further returns from existing investment in design and production technology

The relative performance of this programme against other such programmes has not been determined. Whilst studies are available that catalogue the performance of BPR exercises, notably those involving the implementation of IT systems, they generally lack relevance to this programme. The use of a time-based approach, the application of this approach to the adoption of Internet-based ICT and the implementation of these technologies into SMEs are all factors not typical in BPR projects. Therefore this approach appears to be unique both in terms of its approach and in the manner of implementing ICT in SMEs. Given that efforts to implement Internet technologies in small companies are likely to accelerate, the results of this innovative research will serve to act as a reference for future programmes.

14 Recommendations

The following four recommendations resulted from the analysis of work undertaken during the AutoLean project.

1. The benefits of Internet-based ICT should be promoted to supply chain and procurement executives in OEMs and large first tier companies. The performance improvements demonstrated by the small companies in this study were broadly achieved in isolation of any co-ordinated effort from their customers to improve supply chain performance. Were these harnessed to work in a coherent manner across the supply chain then massive benefits, especially in new product development, are available to all parties. Therefore a review of the data should be undertaken to determine ways in which this potential can be demonstrated.

2. The characteristics that differentiate between success and failure in the implementation and application of ICT remain unclear. Efforts should be applied to identify and quantify them. This would allow a predictive tool of the likely success of undertaking such a project to be devised. Project managers in programmes like AutoLean and companies themselves would benefit from the ability to identify where resources should be best applied. Such information would also aid decisions on whether implementation should be attempted or aborted.

3. The AutoLean programme involved the adoption of ICT in twenty-one SMEs. In order to draw more robust conclusions regarding the effectiveness of the methodology used to implement the ICT capabilities and their effect on business performance, application in a larger sample of companies is required. This Research Engineer designed and secured funding for a follow up programme, AutoLean 2, that aims to apply the methodology in a further seventy-five companies, a two-year task commencing in August 1999.

4. The time-based approach to performance improvement was demonstrated as able to provide understanding of businesses processes through its approach to assessment and analysis. This approach may have transferability to guide other types of business improvement. Candidates for this include the adoption of 'lean' practices, an area of improvement where a successful route map for implementation remains elusive. Therefore methodology transferability should be tested through its application in other areas.

Research Phase 5: Implementation of Recommendations

15 Time-based Supply Model.

The promotion of the benefits of Internet-based ICT was the first of the recommendations from the AutoLean project. In order to achieve this aim, this section presents a technique for giving a supply chain context to the improvements achieved in individual company performance. With a focus on responsiveness and the use of a time-based approach to improvement it seemed appropriate to model the supply chain from the perspective of time.

The Time-based Supply Model is described in detail in Submission 4-4, Time-based Supply Model, where data collated from automotive component suppliers during the AutoLean programme was used to populate the model and illustrate its application. A summary of this work is presented here.

A philosophical approach to problem decomposition has been developed but not published by J. David Alexander of Warwick Manufacturing Group, University of Warwick. Termed the “W-Cycle”, it illustrates the flow of information and material along chains. This model forms a template against which supply chains can be analysed. This provides an insight to supply chain practices, especially the incidence and management of risk. The model is shown below in Figure 6 with tiers named to represent an automotive supply chain.

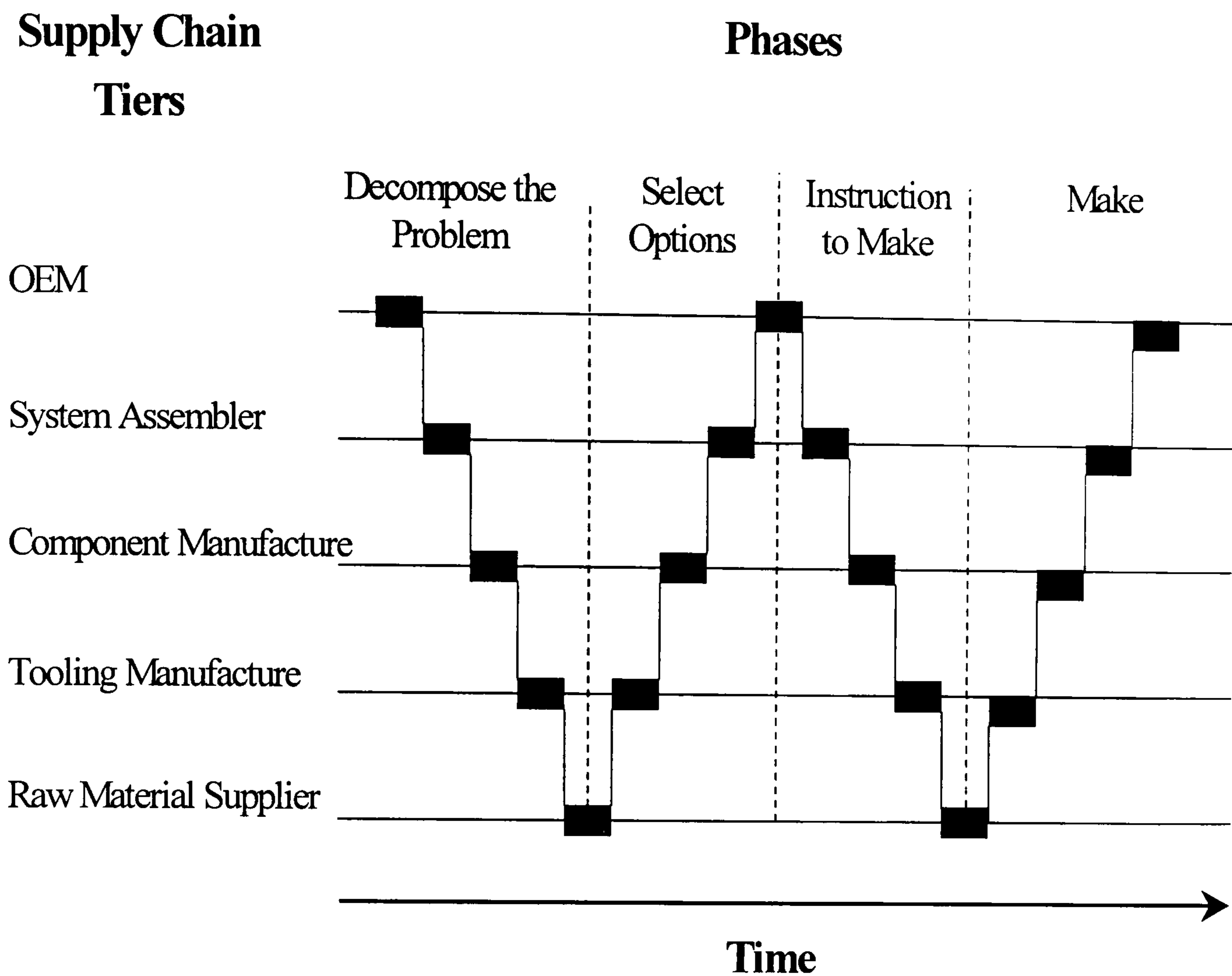


Figure 6. The W-Cycle.
(Source: J.D. Alexander, unpublished)

15.1 Description of the W-Cycle.

Creating a new product begins with the desire for something new. This may result from a customer expressing a need or from research where a company identified a market opportunity. This need is described in terms of a problem that needs solving. The problem decomposes down the supply chain where companies are asked to use their respective expertise to propose solutions to parts of the problem.

When the problem reaches the bottom of the chain, supplier options are fed back up. Successive tiers of customers select from the options, incorporating successful ones into their

own solutions which pass up to the next tier. Finally in this phase, the head of the supply chain makes the selection.

The decision on which option proved successful is passed back down the chain via an instruction to start production. Upon receiving an instruction, the lowest tier supplier makes their parts, which are delivered up the supply chain. This production activity continues up through the tiers until final assembly where the product is shipped to the customer.

The first two phases, 'decompose problem' and 'select options' form a cycle. This operates when something new is required. In essence they form a simple model of the design cycle. This is idealised as it assumes right first time, sequential design with no iterations. This obviously fails to reflect the uncertainty and high levels of communication in actual design but it does however illustrate the logic of design. In particular, it describes how a problem needs to flow down through supply chain tiers in order to reach the most appropriate point for it to be solved. Building these solutions into a final, integrated design occurs as customers higher up the chain combine solutions developed by their suppliers.

Firms often break this cycle by failing to decompose the problem and creating solutions based on forecasts and experience of supplier capability. This may prove necessary in the short term to respond to demands for shortened product development times. Where this is the case, the model is useful in identifying where customers are taking risk. For example, buffer stock between a supplier and their customer exists where product has been made in advance of a specific order. By holding buffer stock the supplier incurs risk. In this instance the risk is that the buffer stock could become obsolete. This is an example of one of the risks in the supply chain caused when the phases are not operated as full cycles up and down the tiers.

15.2 Time-based Supply Model.

The Time-based Process Mapping of the business processes of automotive component suppliers undertaken during the AutoLean project provided data to populate the supply chain model. This data was aggregated and an average value was used for each stage of the supply chain processes. The result of this exercise is presented in Figure 7.

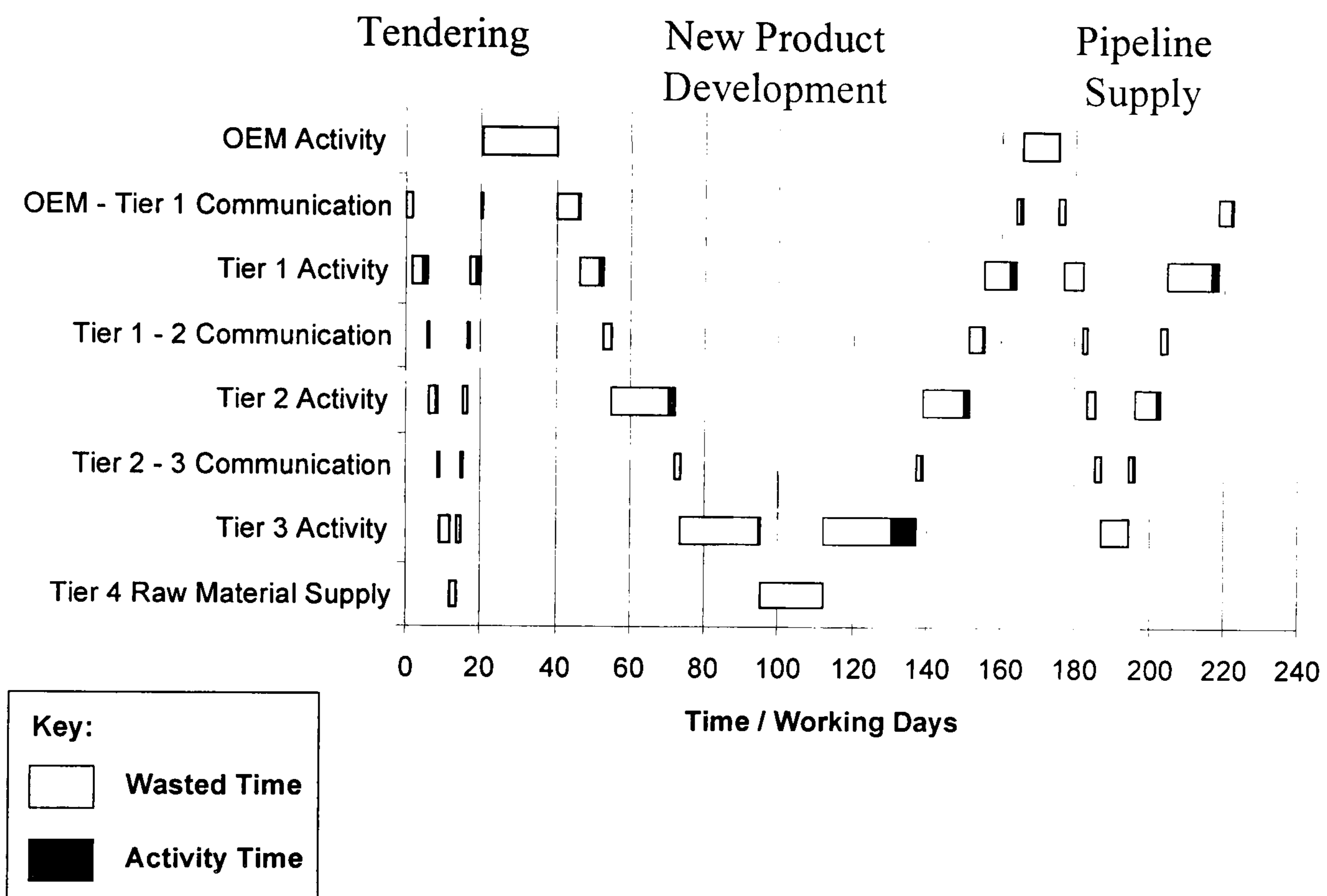


Figure 7. Automotive Component Industry Time-based Supply Model.

This development of the W-Cycle uses the semantic and syntactic formats of Time-based Process Mapping to graphically represent the consumption of time across the supply processes. This combination creates what is termed here a 'Time-based Supply Model'. This not only allows the structure of the supply chain to be modelled, it allows its performance to be assessed.

Documenting the supply chain in this way helps organisations to view their transactions and relationships from a wider perspective. This will provide an understanding of the processes that exist within complex, networked supply structures.

Constructing such a business process model provides a tangible, collective picture that shows how supply chain business processes work. Given that the existing processes have never been described or even viewed as processes in a simple manner such as this, it is possible that such a model can establish a common ground of understanding amongst the constituents of the supply chain (Maull, Childe, Bennett, Weaver and Smart, 1995). This is essential in order to communicate the need for improvement (Davenport, 1993).

The benefits of developing a supply chain process model do not necessarily result from having a complete or totally accurate model. Instead, the benefits are more likely to result from the communication of understanding (Maull et al, 1995). The act of creating the model can develop the critical momentum required to change existing behaviour. In doing so, the Time-based Supply Model is proposed as a vehicle that has a significant potential to promote both a time-based and process-orientated perspective to supply chain improvement. This is likely to have generic relevance in the pursuit of improved responsiveness across the supply chain. In this capacity it will have value in the specific task of promoting the time compression and responsiveness benefits of introducing Internet-based ICT into SMEs to the supply chain and procurement executives in OEMs and large first tier companies whom are essential in driving and co-ordinating their adoption.

16 Performance Improvement Programme Management

Project work undertaken over the course of this programme of research into performance improvement has provided the opportunity to observe and consider various aspects of the subject. Following the Action Science approach to the application of innovation allowed new phenomena encountered to be examined, which provided the basis on which to build new hypotheses. One such example was the observation that on a number of occasions, a problem of undertaking improvement was the management of a number of alternative, viable ideas for improvement. Often a large number of ideas that could lead to improved performance were identified during the investigation of a process. It was usually necessary to have to choose between these ideas, as the resource available was always limited and certainly less than that needed to implement them all.

None of the projects undertaken during the earlier phases of this research programme used a mechanism for managing the choice between ideas. Consequentially, choices were always made intuitively, on an ad-hoc basis. In light of this observation, it appeared that the management of improvement programmes could be improved by developing a model that describes the features of this activity.

In response to this situation, the research presented in Submission 5-1, Stage Gate Model was undertaken. This found that a viable solution could be developed based around a stage-gate approach to programme management. A summary of that work is presented here.

16.1 Stage-Gate Approach to Programme Management.

The stage-gate framework for implementing innovation applies the concepts of Cooper's stage-gate new product development process (Cooper, 1990) and Wheelwright and Clark's development funnel for identifying, screening and reviewing product development projects (Wheelwright and Clarke, 1992) to the implementation of performance improvement projects. This concept is shown in Figure 8.

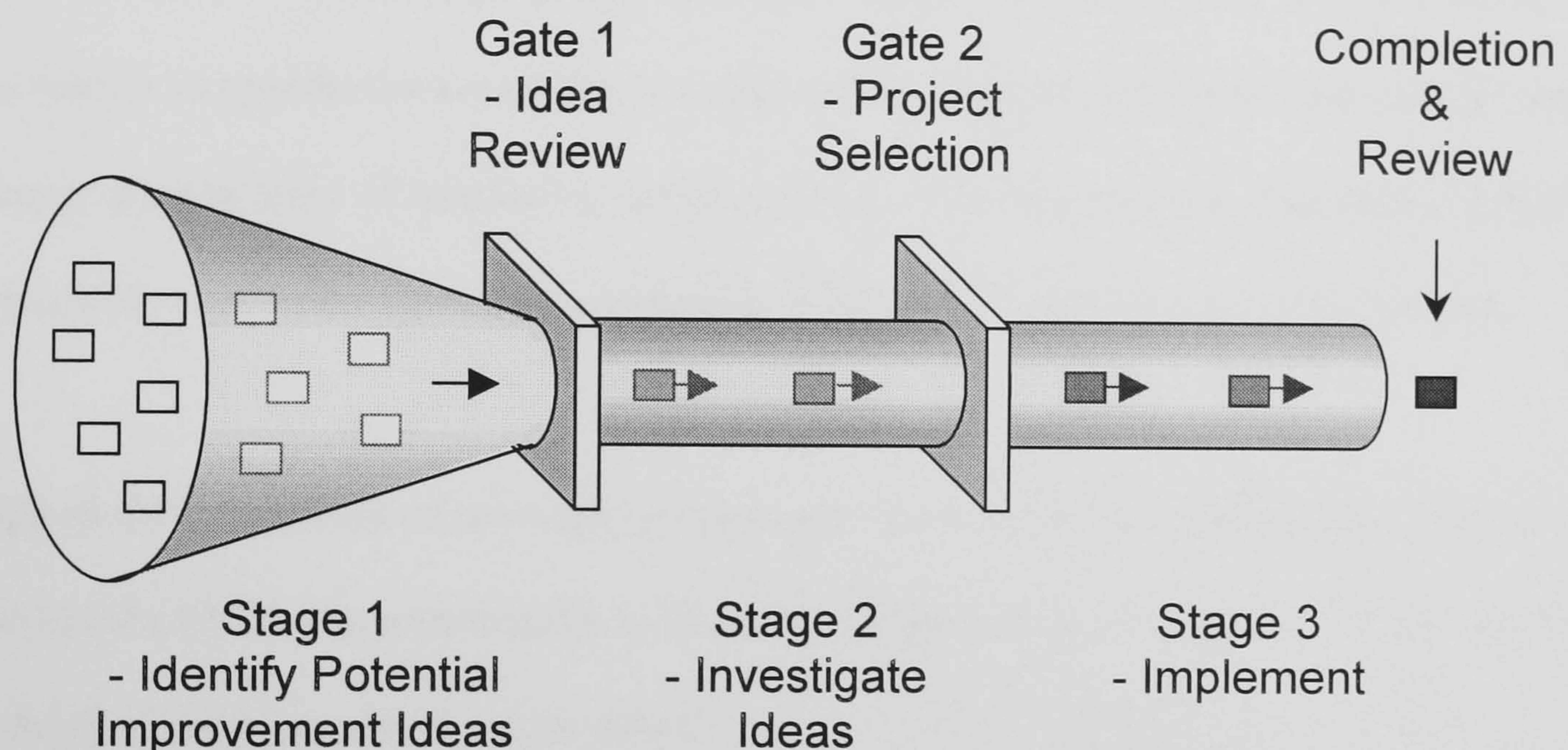


Figure 8. A Stage-Gate Framework for Managing Improvement Projects.

Projects are considered here as objects following a meta-process made up of three stages. Each stage of the process involves undertaking certain tasks on the project passing through it. To ensure a project has achieved its objectives during a stage, a set of criteria that must be met are applied at the end. This assessment forms a gate at the end of the stage, preventing projects moving on from their current stage until they meet the criteria for exit. The gate provides a second function in preventing projects entering the next stage unless the resources needed to advance the project through that stage are available.

The stage-gate concept has been applied beyond its origins in new product introduction by a number of authors (for example: Pisano, 1997; Slack, Chambers, Harland, Harrison, and

Johnston, 1998; Utterback, 1994). These applications extend the use of the concepts however they all restrict their use to specific topics. For example, Slack et al (1998) apply the concepts to the development of new processes and services but not to the ongoing improvement of these activities.

16.2 Discussion.

Instead of restricting the stage-gate programme management approach to specific topics, as is the case, it is hypothesised here that the approach is generally applicable and can be used to manage programmes of innovation projects per se. In particular, it is hypothesised that it is appropriate to use this approach to manage programmes of performance improvement.

Support for the concept of innovation occurring within a structure is offered by Tidd, Bessant and Pavitt (1997) who considered it to be a process that can be managed in a series of phases.

In doing so, two key points are identified:

- “1. Innovation is a process, not a single event, and needs to be managed as such.
2. The influences on the process can be manipulated to affect the outcome – that is, it can be managed.”

(Tidd et al, 1997)

Drawing together the strands of research on the innovation process with that of new product development leads to the hypothesis that the stage gate process framework is a suitable mechanism with which to manage innovation.

In particular, this framework provides a secure foundation for undertaking individual projects (Wheelwright and Clark, 1993) and satisfies factors identified as critical to the success of

programmes of projects (Clarke, 1999). The stage-gate approach therefore provides a solution to the problem described earlier of how to manage programmes of performance improvement.

Integrating the stage-gate approach to programme management with the time-based performance improvement methodology produced a comprehensive model. This model is depicted in Figure 9, overleaf.

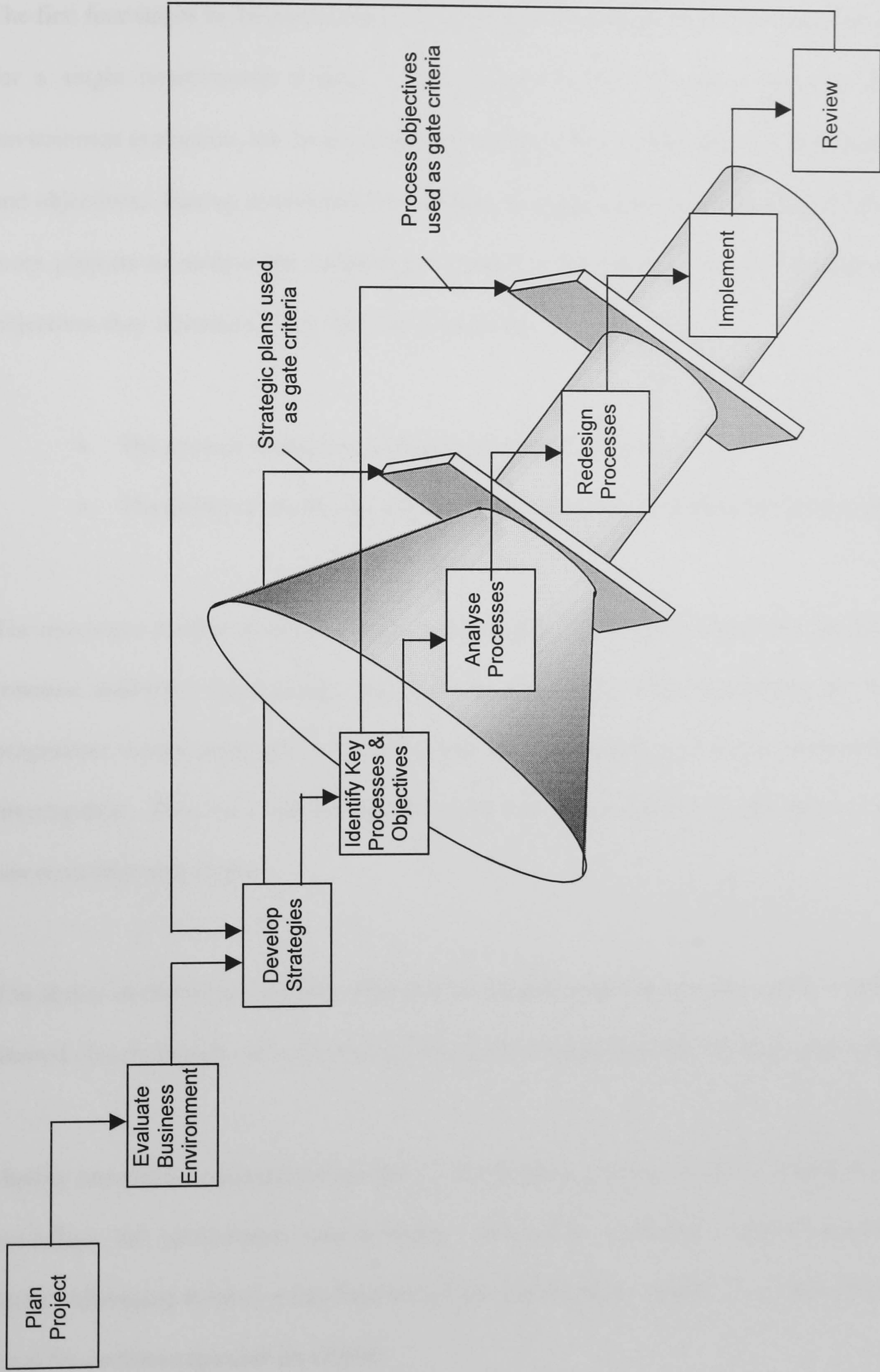


Figure 9. Performance Improvement Programme Model.

The first four stages in the performance improvement programme model are the same as those for a single improvement project. These stages consist of project planning, business environment evaluation, the development of strategies and the identification of key processes and objectives. Having considered these stages, an organisation can choose to launch one or more projects to analyse the selected process(es) in the effort to deliver the improvement objectives they identified. This decision is based on:

- The amount of resource available to analyse processes.
- The ability of the chosen analysis approach to generate ideas for improvement.

The maximum number of projects that can be feasibly undertaken is limited by the amount of resource available. For example, the improvement projects undertaken during this research programme were resourced by a facilitator and a team of people working in the process under investigation. Both the facilitator and the team will have a limit to the amount of time they can contribute to a project.

The ability of the chosen analysis approach to generate improvement ideas able to deliver the desired objectives will influence the decision on how many projects should be undertaken.

Having launched an appropriate number of investigation projects, effort is applied to process modelling and performance measurement. This effort invariably uncovers improvement ideas. Managing these is a key function of the improvement model. Two factors make the need for such management inevitable:

- Not all ideas will align with the strategic plan
- The resource to verify all ideas then implement them will not be available.

The first decision gate provides the mechanism for managing the ideas. It does this by preventing ideas from progressing to the next stage of the model unless a number of criteria can be satisfied. Firstly, the availability of resource that can be used to investigate the validity of ideas is determined. Having established the level of available resource, projects are prioritised. This prioritisation is accomplished using the following criteria:

- Alignment to strategic plans
- Amount of improvement potential
- Resource required to realise potential
- Lead-time to deliver potential.

Resource is allocated to projects according to their rating against these criteria until all of it is assigned. Those improvement ideas with the highest potential, that align to strategic plans and have resource allocated to them progress through the gate to the next stage. Ideas without resource can either be kept on hold and reconsidered when further resource becomes available or killed off.

The second stage involves the investigation of ideas to determine their viability and where appropriate, to use them in process redesign. This redesign creates the future model for the process. This model will consist of a series of improvement proposals linked within an overall structure. Each proposal resolves problems and improves organisational performance. Once again these proposals will need management.

The resource necessary to implement improvements is high. In most organisations it is also scarce. Therefore improvement proposals should be prioritised on the basis of an assessment of their return on investment, likelihood of success and strategic importance, as shown below.

$$\text{Priority} = \frac{\text{Return}}{\text{Investment}} * \text{Likelihood of Success} * \text{Strategic Importance}$$

The intended outcome of an improvement proposal can be assessed against project / programme objectives in a straightforward manner. A projection of the effort required to implement the package can also be arrived at using project management tools and historic data. Therefore those proposals calculated as able to deliver the best return when factored against the risk of achieving these results and the effort required, are given the highest priority. Resource is then allocated to projects in line with this ranking as it becomes available.

One of the characteristics of this approach is that the rules that govern the allocation of resources are made explicit. The intention is that they should be periodically reviewed and amended when necessary in order to maintain the model's alignment to the needs and goals of the organisation.

17 Application of the Performance Improvement Model at British Airways.

A series of three improvement projects was undertaken with British Airways Engineering to improve the productivity of the maintenance, repair and overhaul, MRO, operations of Fleet 2, the long range aircraft based at London Heathrow airport. A full account of this field work is presented in Submission 5-4, 'British Airways Engineering Performance Improvement Programme.' This work is summarised below.

All three improvement groups used the performance improvement methodology to structure their efforts to analyse and redesign operations and implement ideas for improvement in order to deliver a targeted twenty percent productivity improvement in their respective areas. The results from these groups are presented below, followed by a discussion of the implications of these findings.

17.1 Improvement Group Results

The first group, the Service Check Improvement Group, SIG, investigated the Service Check of Boeing 747-400 aircraft. A major output from their work focussed on inspection and maintenance of the 747's Rolls-Royce RB211 engines. The engine maintenance activities were investigated and root causes of waste identified. Solutions to these were developed and the maintenance practices and activities redesigned. Implementation of these solutions delivered the targeted 20% increase in productivity. In delivering these improvements, the team demonstrated that the performance improvement methodology was suitable for application in this new business environment.

The second project team, the Ramp-Check Improvement Group, RIG, analysed working practices in the engineering inspection of aircraft upon their arrival at Heathrow. This work established a partnership between management and operations staff to improve integration between shop-floor trades. The merging of the three separate trades into two groups led to a £500,000 saving through rationalisation of previously duplicated facilities and equipment.

Other changes developed by RIG reduced the time spent by engineers travelling around Heathrow from the central store and crew room to parked aircraft. This was achieved by reorganising work allocation, improving housekeeping at aircraft stands and developing a tools and equipment kit for resolving common defects uncovered during the inspection. The result of this work has been to reduce the number of journeys to and from aircraft and the number of vehicles needed to make them, which has led to a 20% improvement in productivity.

The third project to be launched was the Tech-6 Improvement Group, TIG. 'Tech-6' is the area for casualty repairs and heavy and unscheduled maintenance. TIG took a different approach to improvement to the other two groups and focussed its efforts on delivering small scale, local operational improvements to resolve problems and frustrations faced by staff on the shop floor. In this arena the TIG produced solutions to a variety of problems brought to them by shop floor personnel and shift managers. An example of this is the work is the development of kits of the seals used when overhauling engine modules. The availability of these kits in the stores saves between two or three days each time a kit is used. To date, TIG has developed twenty-three such kits.

17.2 Improvement Programme Management.

The scale and scope of the projects tackled by the improvement groups led to a large number of ideas for improvement being raised. Whilst most were sound ideas, many did not relate to the objective of the project groups. Application of the performance improvement model helped the groups make decisions on which ideas to focus their efforts upon. As a result of using the model the groups felt they had been able to make better decisions on the allocation of resource.

It was found that the groups did not use the model as a regular aid to project management or resource allocation. Instead, it was used on an occasional basis to take stock of progress and to realign the group against their objectives. Such project reviews tended to occur when they lost direction and they required a quick review of their position. The model proved to be a tool that could summarise the work being undertaken at a given point in time. This summary could then be compared against the terms of reference established when the group was launched.

Using this approach to project review, it was found that both SIG and RIG had concentrated their efforts to deliver their large, strategically directed projects. Whilst these groups worked on a number of individual projects, e.g. zonal working and grab bags in RIG, these were aligned to a larger goal. This alignment of individual projects to the overall goal was demonstrated by the use of the project terms of reference to determine which of the potential projects should be pursued. To achieve that end the groups adopted a structured approach to their work by following the performance improvement methodology.

17.3 Conclusions.

The performance improvement methodology proved successful in providing structure to the efforts of the groups. During this application an additional tool, activity sampling, was incorporated into the methodology to collate data in order to assess the effectiveness of bottleneck activities.

The performance improvement model was used to provide a context to manage the improvement groups more effectively and allocate resource more efficiently by using a robust approach to decision making. Having understood the importance of good decision making, the criteria for making these decisions were developed so they could be made in a visible and structured way. The effect of taking this approach to managing projects was to:

- Draw more of the team into the decision making process.
- Expose the criteria against which decisions were being made, allowing them to be examined and improved.
- Help justify why particular courses of action had been taken.

A major deliverable from all three project groups was the improved co-operation between management and shop floor in undertaking improvement activities. Not only did this underpin the specific achievements of the project groups, it is a result that should lead to further improvements in the business over time.

In summary, BA Engineering was a new environment for the application of the performance improvement methodology. This application proved success with the methodology able to help guide project execution. Application of the stage-gate approach to programme management found the model able to provide improved understanding that helped project management.

18 Management of Decision-Making in Improvement Programmes.

This second piece of research into the Performance Improvement Model investigated the ability of the assessment criteria used at the second, final gate to determine the likely success of a project. A full account of this research is presented in Submission 5-3, 'A Retrospective Assessment of Internet ICT Adoption in SMEs.' This investigation studied the twenty-one companies that sought to implement new Internet-based information and communication technologies, ICT, and their associated business practices in order to improve performance during the AutoLean project. A summary of this work is presented below.

Research undertaken during the AutoLean Programme found that the ability to predict success in projects to integrate Internet-based ICT into business processes would enable companies and the agencies that support them to improve their return on these investments. However, it was found that the characteristics that differentiate between success and failure in the implementation and application of ICT were unclear. Therefore it was recommended that these factors should be investigated in an attempt to identify and understand them.

The key to prediction in this situation lies in the criteria used to make the decision on whether or not to implement recommendations made following the investigation of an organisation's processes. In the context of the stage-gate improvement programme model, this decision occurs at the second gate. In the case of AutoLean projects, up until this point of the improvement process, investment in the project by both the company and the supporting agencies was limited to half a day of business analysis. A decision to go ahead and invest in the installation of the ICT system, would commit the business to a substantial investment in time and effort and the funding body would be committing the money to pay for it. At this

stage of the innovation process a decision informed by a prediction of the likely success of this implementation would be valuable.

18.1 Characteristics that Influence Project Success.

An assessment was made of the characteristics considered important in the adoption of innovation. These characteristics were derived from the investigation into the nature of innovation presented in Submission 5-1, Stage-Gate Model. This investigation identified Farr and Ford's, 'contributing factors of innovation' as the overarching characteristics (Farr and Ford, 1990 in West and Farr, 1990). These factors are considered here in the context of their effect upon the transition from the use of one set of business practices to another. This context is shown in Figure 10, below.

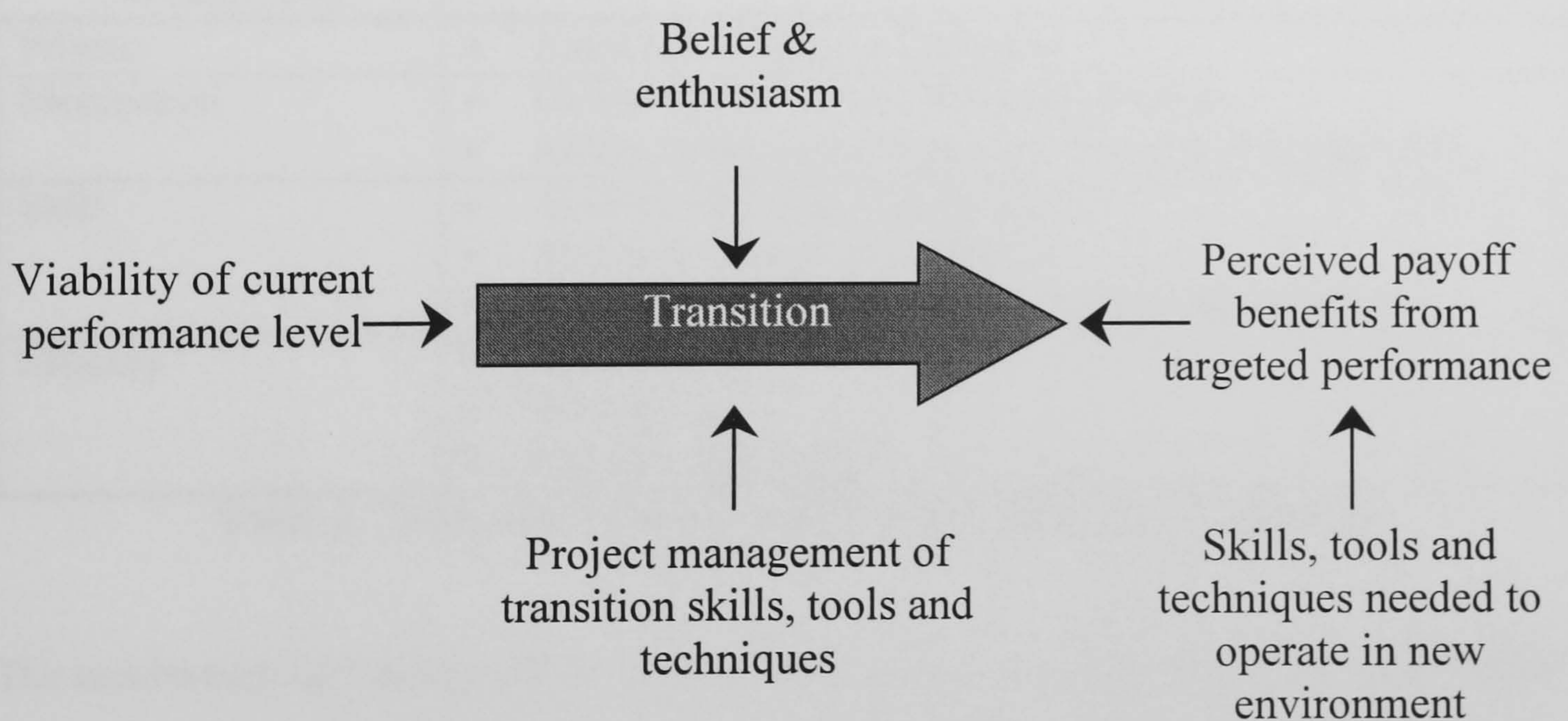


Figure 10. Performance Improvement Transition Forces.
(Adapted from Ford & Farr, 1990)

This representation of the transition forces that contribute to innovation implies that there is the need for momentum in order to change from one set of business practices to another. This momentum stems from a recognition that current practices are unviable, together with the

perception that benefits will result from undertaking the change. Underpinning the change are the skills to understand the need to change, the skills to be able to make the change happen, such as project management, and the skills to operate the new practices successfully. In addition, those making the change must be convinced that the change is necessary and believe in their ability to deliver it.

18.2 Application

Each overarching innovation characteristic was interpreted with respect to the circumstances of the AutoLean Programme. This identified the sub-characteristics of innovation shown in Table 2, below.

Overarching Characteristic	Sub-Characteristics
Priority	<ul style="list-style-type: none"> • AutoLean Priority in Company
Momentum	<ul style="list-style-type: none"> • Unviability of Current Working Practices • Ability to Articulate Perceived Benefits of Internet ICT
Skill	<ul style="list-style-type: none"> • Ability to Analyse Current needs • Ability to Manage Projects • Ability to operate a PC system and the Internet ICT
Efficacy	<ul style="list-style-type: none"> • Enthusiasm • Persistence • Previous Experience

Table 2. Innovation characteristics of the AutoLean Programme

The mechanism for testing the innovation model was an investigation into the characteristics and consequences of the innovation projects undertaken by the twenty-one companies that participated in the AutoLean Programme. This investigation involved undertaking interviews at each company with a senior manager familiar with the AutoLean project, usually the person responsible for implementing it. The interview was structured around a questionnaire with the information collected subsequently compiled into a report and validated by the interviewee.

The results of this investigation found a strong positive correlation between the level of innovation attained and each of the four overarching characteristics of innovation.

18.3 Discussion

The findings of this investigation provide evidence to support the hypothesis that the characteristics of innovation in small firms resemble those that contribute to innovation in individuals. In doing so they support the hypothesis that these characteristics can be employed as a mechanism for predicting the likely success of improvement projects.

The ability to undertake such assessments would enable project managers to make better informed 'go / no go' decisions on projects. If the decision is 'no go' they have information available on which to make a better-informed decision between killing or keeping the project. If they decide to keep the project then the findings of the assessment will help direct resource to resolve its deficiencies before reassessing its suitability for implementation. Where the decision is to 'go' then investment can be optimised by allocating resource where necessary whilst making savings on those aspects of the project that are already well developed.

Whilst this approach shows promise, the rules applied at the gates to manage the flow of projects though the process were developed to suit the AutoLean Programme. In order for this work to become generally applicable templates need to be developed that describe the general nature of the rules. These would need to be supported by advice on how to apply them so they could be adapted to suit the circumstances of alternative applications of this approach.

Summary

19 Catalogue of Innovation

The portfolio of work summarised in this Executive Summary presents the development and application of a Time-Based Performance Improvement Methodology. This innovative methodology consists of a General Approach supported by a tool-kit of techniques and tools that provided the means to take a time-based approach to improvement activities that supports continuous improvement and employee involvement in performance improvement. The toolkit included Time-based Supply Chain Mapping, a new technique developed to model processes across supply chains from a time-based perspective.

Application of the methodology was undertaken in two phases of fieldwork. The first phase used the methodology to structure a programme of facilitated workshops. These projects achieved their immediate objectives of defining and analysing processes and delivering recommendations for improvement. They did so in significantly less time and at less cost than previous, comparable projects. Where the recommendations were implemented, significant performance improvements were achieved.

The second phase of application used the methodology as the basis for an innovative tool for auditing SME business performance. This audit met SME needs in that it was quick, cheap and effective. Twenty-one SMEs were audited and presented with recommendations that directed their adoption of Internet-based Information and Communication Technologies. This work led to nineteen companies adopting the technologies with sixteen of them demonstrating performance improvements as a result.

The understanding gained during this work led to the development of an original approach to managing performance improvement projects. This used a stage-gate framework overlaid on

the performance improvement methodology. The stages of this framework consist of the steps of the general approach and the gates are decision points based on criteria developed by a novel application of the contributing factors of innovation in individuals to small team performance improvement.

Integrating the Time-Based Performance Improvement Methodology with the stage-gate approach and the decision-making criteria culminated in the development of the Performance Improvement Model. This innovative model was applied to help structure and manage three improvement groups at British Airways Engineering. This application found the model to be suited to application in this large company, service environment where it helped deliver significant cost saving, increased productivity and improvements in industrial relations.

20 Conclusions

The research undertaken over the period of registration on the Engineering Doctorate Programme has led to the development of a Performance Improvement Methodology, which was subsequently developed into a Performance Improvement Model. This outcome serves to satisfy the original research question, that is, these devices constitute the development of a Time-Based Performance Improvement Methodology that possesses general applicability.

20.1 Performance Improvement Methodology

The Time-Based Performance Improvement Methodology is an innovative piece of work grounded in fieldwork, verified through desk research and validated through application in the field. Its application has been shown to improve the speed, cost and outcome of improvement projects and as a consequence was able to improve the competitiveness of a number of companies.

The methodology took a time-based approach to improvement that used techniques and tools selected to develop capabilities and support employee involvement. The use of time as the key performance measure allowed the swift gathering of evidence that quantified performance, demonstrated the need to improve and prioritised the areas on which improvement efforts were focused. Techniques and tools selected to support these activities were chosen on the basis of their ability to provide understanding through their simplicity. This attribute helped develop the capabilities of company employees, allowing them to build upon benefits initially achieved through further cycles of improvement.

The methodology was applied and tested during four substantial projects, two in SMEs and two in large organisations, and during focused projects in twenty-one automotive SMEs. This mix of company characteristics in which the methodology was applied is illustrated in Figure 11, below.

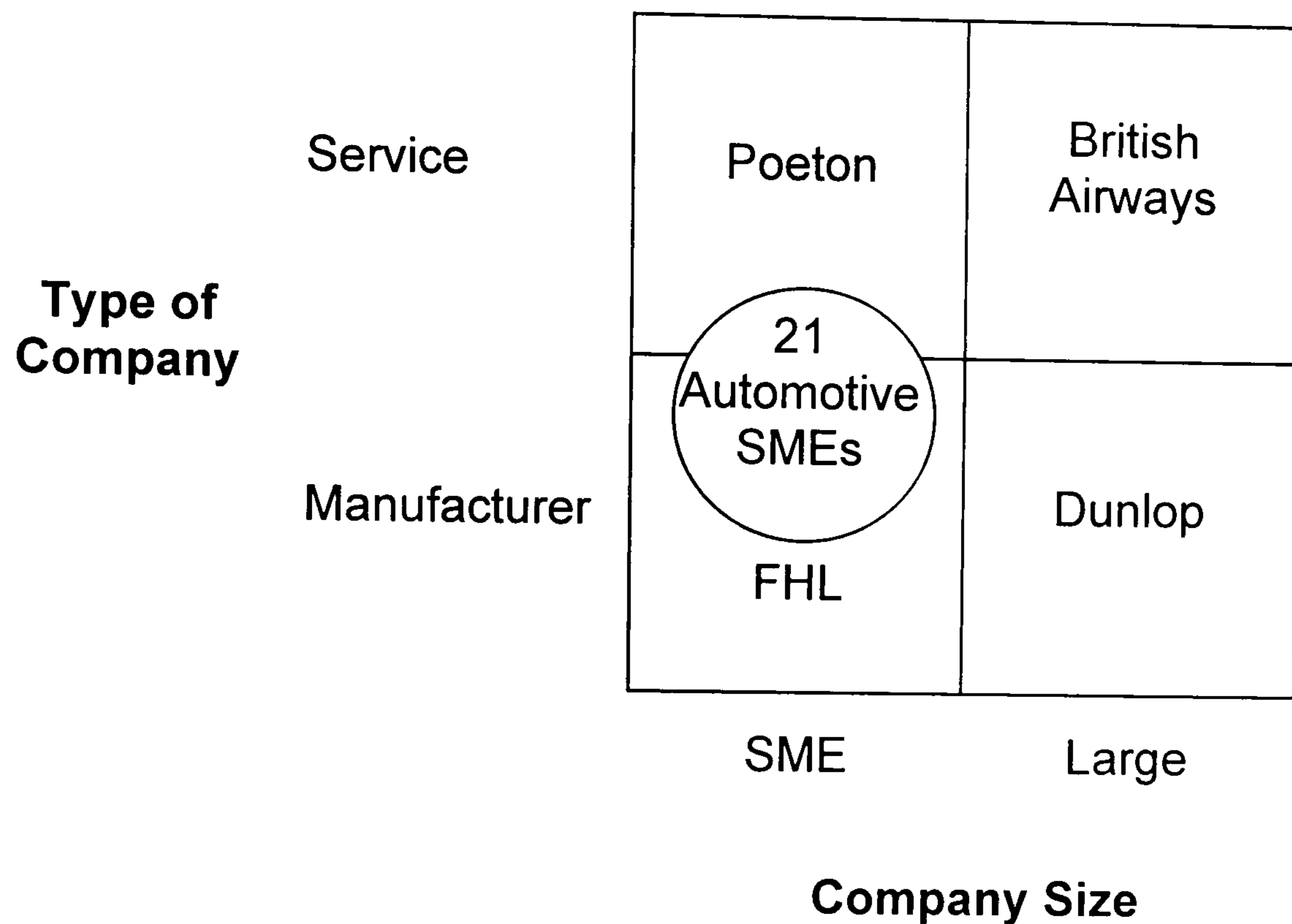


Figure 11. Characteristics of the Companies where the Time-Based Performance Improvement Methodology was Implemented.

The very diversity of the organisations in which this research was conducted shows that this methodology is robust. Formulation of the Performance Improvement Methodology and the subsequent Performance Improvement Model during work with SMEs and large companies, manufacturers and service companies, indicates wider applicability than would have been the case if the work had been undertaken in a limited range of environments.

20.2 Performance Improvement Model.

Process improvement is an activity that all businesses need to undertake, although most carry it out intuitively. The ad-hoc approach does not support consistency in either the alignment of improvements against strategic needs or quality of implementation. The Performance

Improvement Model structures a company's approach, therefore it is likely to improve a company's ability to deliver process improvement projects that are better aligned to strategic needs, in a more consistent way, in a shorter time frame and at lower cost. The simple framework used by this methodology combines the ability to reach informed decisions on project selection with an improved ability to implement the chosen projects through robust project management.

Adoption of the Performance Improvement Methodology is more cost effective than an ad-hoc approach because it aligns improvement projects closer to company strategy and it ensures projects are thoroughly planned before being implemented. In addition, the methodology helps identify inappropriate projects earlier, which can be terminated thus saving resources. Devolving decision making to a lower, and therefore cheaper, organisational level also reduces costs.

It is recognised that the quality of decisions in the process relies upon the quality of the criteria used to reach them. Whilst the criteria are company specific, depending upon circumstance and strategic ambition, providing visibility of the criteria and their application will tend to expose weaknesses should they exist. This transparency allows the framework to be assessed against its own set of objectives and refined accordingly.

This research found that the contributory factors of personal innovation could be transferred to describe the nature of innovation in small firms. These factors were interpreted to align with the characteristics of innovation in small firms and to the implementation of Internet-based information and communications technologies, ICT. As such, they proved to be capable of being used to assess the likely success of such projects in these firms. Specifically, a strong correlation was found between the success of ICT adoption and the presence of the innovation characteristics.

This finding provides support for integrating these measures of likely innovation success into a stage-gate model to create a model of the innovation process. This model represents innovation as a process consisting of three stages separated by two decision gates. The innovation characteristics of the firm can be assessed at the second gate, where the decision is taken whether or not to implement the innovation. Being able to assess the likelihood of the success of a project at this point provides valuable information on which to base this decision. In doing so, the stage-gate model of innovation and its incorporation of a technique for predicting the success of innovation projects will provide a valuable tool for managing programmes of innovation projects.

Considering innovation projects in terms of the process that governs their development allows the opportunity for process thinking to be applied to the innovation process as a whole in addition to individual projects. The design of the model, the rules employed at the gates, the length of the process (its lead time) and its capacity (the resource available) can all be assessed and refined in order to achieve a closer alignment of the process of innovation with corporate objectives. This capability will provide people responsible for such issues the opportunity to plan and be more effective in achieving their goals.

20.3 *Review of Human Issues and the Role of Time Compression.*

The aim of the research undertaken and applied during the course of this Engineering Doctorate has been to develop employee capability to undertake performance improvement. The application of these capabilities has been targeted to deliver improvements consistent with Lean Thinking, with the added element of improving responsiveness to uncertain changes in customer requirements, i.e. to become more 'agile'. This author also had the

opportunity to study lean manufacturing in broad terms during his work on the Lean Aerospace Initiative.

Results from the case study projects undertaken over the course of this research programme show that the performance improvement methodology developed by this author was a valuable aid to process diagnosis and design of performance improvement solutions. However, significant variation in the results achieved by the various companies where the methodology was applied need to be acknowledged. Addressing the issue of variation in the results from this programme of work leads to two important areas that need to be acknowledged. The first of these is recognition of the strong impact of human issues upon improvement projects and the second is the recognition of the premise that time does not always need to be reduced.

Even from a technically rational approach to performance improvement, variations in the human issues surrounding improvement are significant. To illustrate some part of this variation, it is worth considering the human issues that can affect an improvement project.

Some of the human issues to consider along the life of an improvement project are:

At the outset:

- Current level of personnel capability.
- Prior experience.
- Enthusiasm.
- Organisational structure.

During the project,

- Group dynamics.
- Changes in group personnel.

-
- Ability to absorb fresh information and consider alternative view points.

Following the project

- Articulation of experience and capture of new knowledge.
- Maintenance of new ways of working.
- Ability to apply capability to new challenges.

This list of human issues presented above is not intended to be comprehensive. Its aim is to illustrate the point that human issues are a significant aspect of any improvement activity and deserve due consideration. Whilst efforts were made to take account of these and other human issues during the course of this research programme inevitably there are a host of areas where value judgements were made that can, in retrospect, be improved upon.

The second area of this research that needs qualification is the recognition that time does not always need to be reduced in business processes. In some instances, the lead time of a process is dictated by its need to synchronise with the inputs and outputs to other processes. These processes may be operated by other companies, the performance of which is not possible to influence. In such a situation, lead time reduction undertaken in isolation may disrupt important harmonisation in information and product flows. It may also be that customers may not perceive the benefits of reduced time in a supply process. In such a case, even if real benefits exist, time compression that a customer perceives as detrimental should be avoided.

21 Recommendations.

Many issues were raised over the course of this programme of research into performance improvement that could not be answered immediately. Consequentially, additional research has been identified that would provide a better understanding of performance improvement. This has been organised into four key areas of research, which are identified below.

1. The development of the stage-gate improvement model, and understanding of its potential, remains in its infancy. To date it has proven useful in describing the management of one performance improvement programme and explaining the nature of decision making in another. Both of these aspects of the model need to be explored further both conceptually and in practice in order to determine fully their validity, boundaries of generality and usefulness.
2. It is possible that the stage-gate approach to performance improvement projects may have a wider applicability and be useful in managing innovation programmes per se. However, this hypothesis needs to be tested and therefore further work is required.
3. This portfolio of research demonstrated the value in incorporating criteria for predicting success of a project into the gates of the stage-gate model. This tool may be useful in other applications of the stage-gate model, such as new product development, and should therefore be investigated.
4. The decision rules that manage project progression and the allocation of resources were based on a model of innovation in individuals. This was found to have value when applied to innovation in SMEs, whose organisational structure is typically run from its centre and autocratic in style. This characteristic makes innovation in small firms similar to innovation

in individual people. It may be that the same is not true at the team level of larger companies. Therefore the nature of the factors that govern decision making in organisations should be investigated in order to test the extent to which the characteristics of innovation in individuals can be generally applied.

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