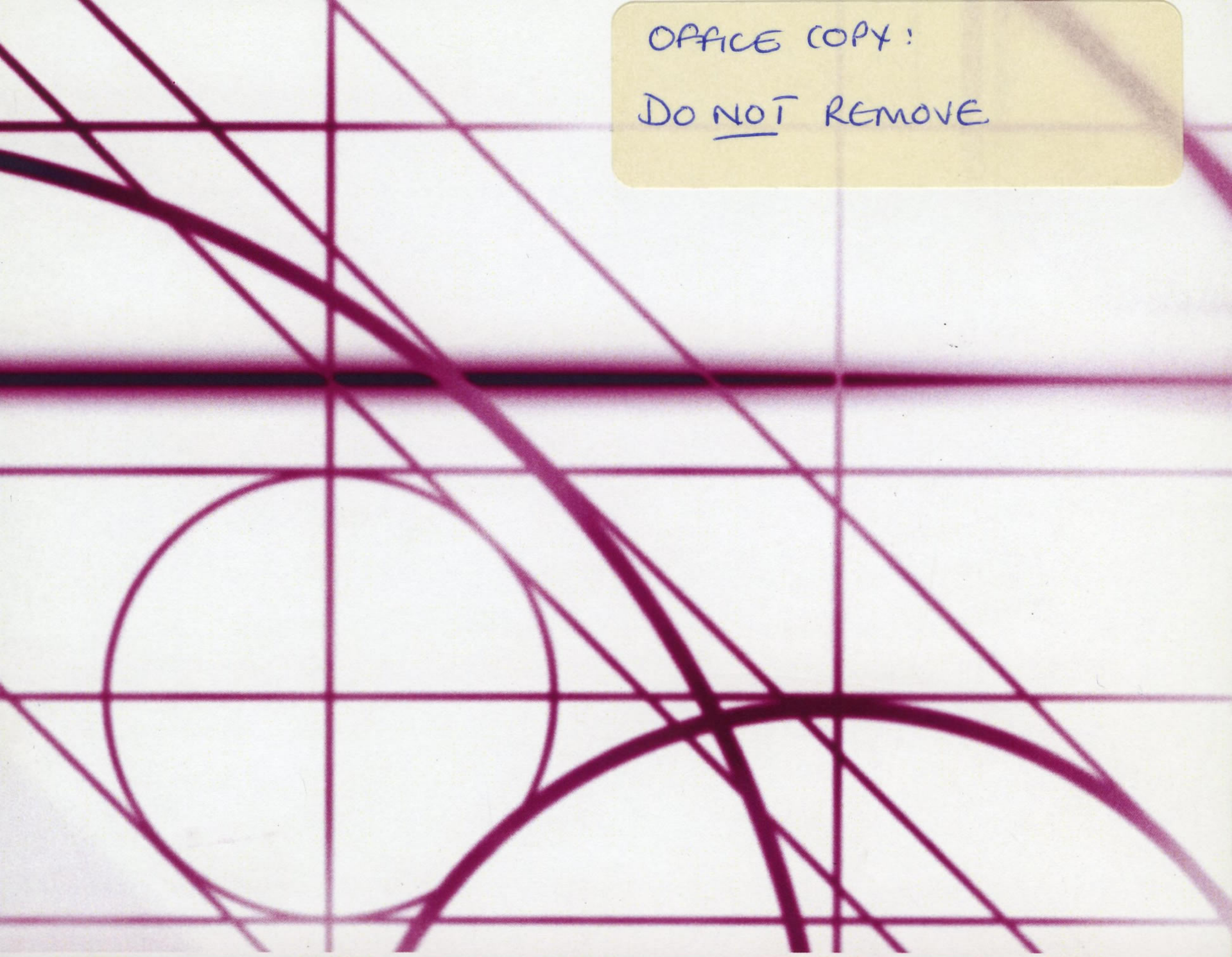

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IMPROVING DESIGN MANAGEMENT TECHNIQUES IN CONSTRUCTION

By
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A Dissertation Thesis submitted in partial fulfilment of the requirements for the award of Engineering Doctorate (EngD) of Loughborough University

September 2003

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PREFACE

The research presented by this discourse was conducted to fulfil the requirements of an Engineering Doctorate (EngD) at the Centre of Innovative Construction Engineering (CICE), Loughborough University. The research programme was supervised by CICE at Loughborough University and funded by the Engineering Physical Sciences Research Council as well as Skanska Integrated Projects and Skanska UK Building as sponsors.

The core aim of the EngD is to solve one or more significant and challenging engineering problems with an industrial context. As such the EngD is a radical alternative to the traditional PhD, requiring the researcher to be located within a sponsoring organisation guided by an industrial supervisor, while academic support is provided by regular contact with academic research supervisors.

The EngD is examined on the basis of a discourse supported by publications or technical reports. This discourse is supported by two journal papers, one conference and two unpublished papers.

The papers have been numbered 1-5 for ease of reference and are located in Appendices A to E to the discourse. While references are made throughout the discourse to the papers there are key reference points in section 4 where the reader is directed to read each paper in its entirety and then return to the discourse. This is intended to reduce the need for the reader to constantly refer to the accompanying papers while reading the discourse.

ACKNOWLEDGEMENTS

I would like to thank the following for their support throughout the course of the research:

Engineering and Physical Sciences Research Council
Centre for Innovative Construction Engineering, Loughborough University
Skanska Integrated Projects
Skanska UK Building

Chimay Anumba	Loughborough University
Tony Thorpe	Loughborough University
Jo Brewin	Loughborough University
Martyn Flowers	Skanska Integrated Projects
Carol Miller	Skanska Integrated Projects

However, I reserve special thanks for my Supervisors. The continued support, knowledge and insight Simon Austin and Dino Bouchlaghem have offered has been invaluable to me over the past four years. Finally, to my fellow EngD students who saw it through to the end, thanks for keeping me sane and motivated during what was a new adventure for all of us.

ABSTRACT

Recent years has seen a significant drive away from traditional procurement routes with contractors finding themselves with an increasing responsibility for control of design - a process they have had little experience in managing. They now have to adapt accordingly. The learning curve is steep, not least because many projects must now be delivered fast track while co-ordinating increasingly complex fabric and content of buildings without a platform of accepted good practice to manage the design process. This is a major factor preventing the UK construction industry from delivering projects on time, to budget and to the specified quality.

There is a need to educate an increasing number of people in design management techniques to equip them to manage today's fast moving and demanding projects. However, many current design management tools are insufficiently developed for industry application. Therefore, to improve design management in the industry, current techniques must be modified to align them with the needs of the modern design manager.

This research has developed and tested a training initiative aimed at improving design management practice within a major UK Design and Construct Contractor. It comprises a Design Management Handbook, Design Management Training, Team Support and Project Monitoring. The Design Management Handbook is the core of the training initiative. It addresses critical aspects of design management practice and provides design management tools. Training provides guidance to project teams on the tools and practices. In Team Support project teams are supported in the implementation of the new practices and tools to help embed new ways of working in company practice. Project Monitoring establishes the impact of the new practices on project performance to demonstrate that they are working and thus reinforce change.

To establish the training initiative's effectiveness and key findings, the impact of the initiative on design management performance has been explored. The research has established which practices and tools were used, which were not, as well as an understanding the applicability and performance of each Handbook practice and tool. From this, barriers to implementing new design management tools in industry were identified and strategies developed in order to overcome such barriers.

DISCOURSE CONTENT MAP

Figure 1 shows the discourse contents and illustrates where discourse sections refer to sections of one of the five papers (or even the paper in its entirety) in Appendices A to E. Paper 1 is concerned with developing and understanding the research problem, and defining the improvement strategy for the sponsor. Paper 2 discusses the early development of the training initiative and how key implementation barriers were addressed. Paper 3 summarises an extensive description and review of the training initiative. Paper 4 reports on the impact of the training initiative on the sponsor's design management and project performance, identifies implementation barriers and explains how they were addressed in a case study exercise. Paper 5 focuses on the research effort to develop and test a set of design process performance indicators.

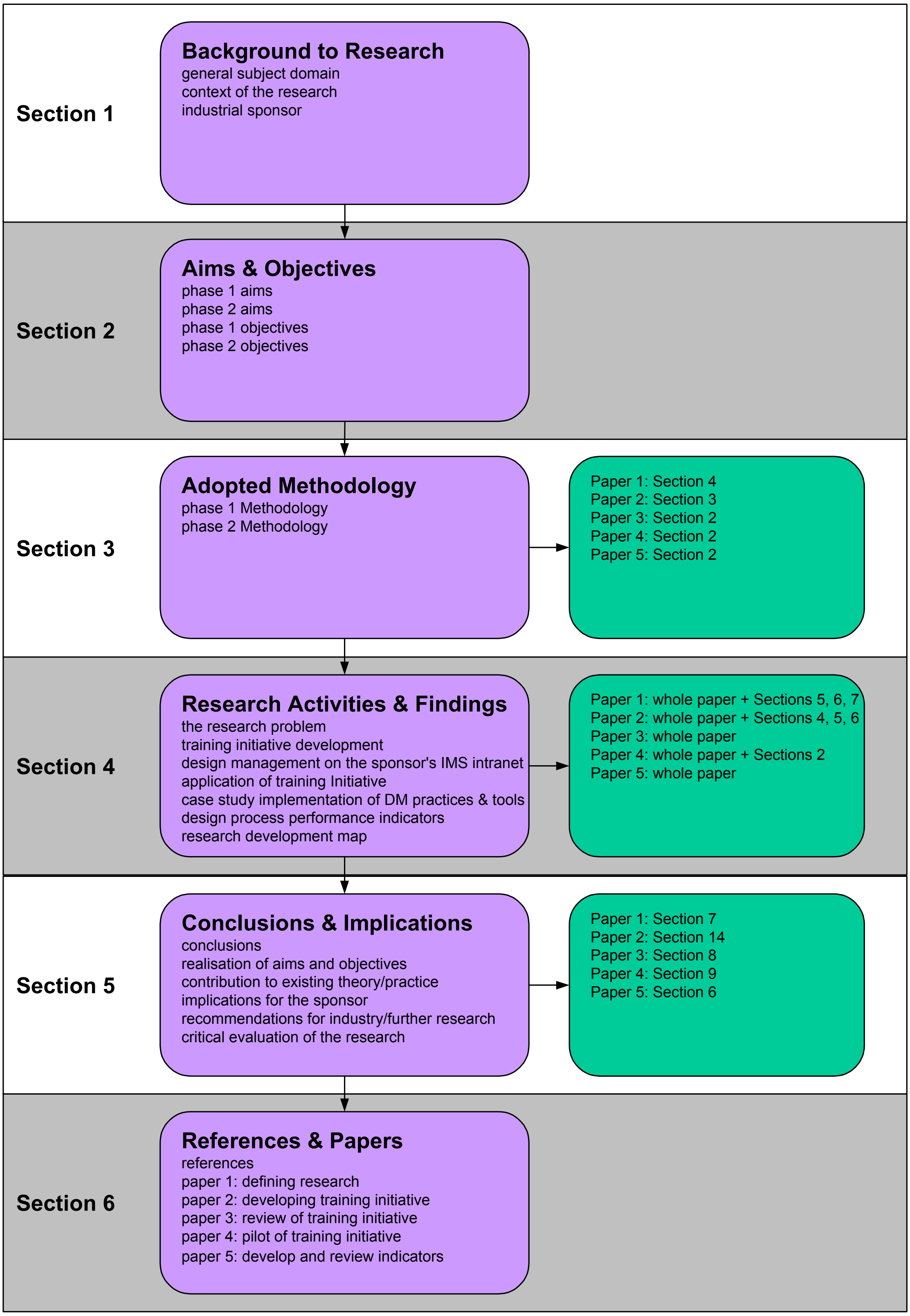

Figure 1: Discourse Content Map

KEY WORDS

Construction, design, management, industry practice, process, tools, training, performance, measurement.

USED ACRONYMS / ABBREVIATIONS

CE	-	Concurrent Engineering
D&B	-	Design and Build
DFMA	-	Design for Manufacture and Assembly
DM	-	Design Management
DMH	-	Design Management Handbook
DPPI	-	Design Process Performance Indicator
EngD	-	Engineering Doctorate
FMEA	-	Failure Mode and Effects Analysis
IMS	-	Integrated Management System
IMVP	-	International Motor Vehicle Programme
ITS	-	Information Transfer Schedule
JIT	-	Just–in-Time Manufacturing
LAI	-	Lean Aerospace Initiative
LRM	-	Last Responsible Moment
NPD	-	New Product Development
PDMP	-	Project Design Management Plan
PFI	-	Private Finance Initiative
PPP	-	Public Private Partnership
QFD	-	Quality Function Deployment
RFI	-	Request for Information
SIP	-	Skanska Integrated Projects
SUKB	-	Skanska UK Building
UK LEA	-	UK Lean Aerospace Initiative
VSAM	-	Value Steam Analysis and Mapping

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1 BACKGROUND TO RESEARCH

1.1 GENERAL SUBJECT DOMAIN

1.1.1 The Construction Design Process

The construction design process is a specialised and highly demanding form of problem solving (Pressman, 1993; Lawson; 1997). It is where stakeholders' needs and requirements are conceptualised into a physical model of procedures, drawings and technical specifications (Freire and Alarcon, 2000). It is a dynamic and complex multi-disciplinary process, involving many parties and performed in a series of iterative steps to conceive, describe and justify increasingly detailed solutions to meet stakeholder needs (Sterman, 1992; Ogunlana *et al*, 1998; Baldwin *et al*, 1999). It is claimed to be the key project process (Morris *et al*, 1999; Cockshaw, 2001), defining up to 70% of the final product cost (Kochan, 1991) and adding value by delivering functionality, quality, enhanced services, reduced whole life costs, construction time and defects as well as delivering wider social and environmental benefits. (Treasury Task Force, 2000; Prescott, 1999).

There are several defining features of the process that have been noted (Frankenberger & Badke-Schaub, 1998; Austin *et al,* 1996; Ballard, 2000; Kalay *et al*, 1998; Kvan, 2000; Lawson, 1997; Reinertsen, 1997; Ulrich and Eppinger, 1999; Austin *et al*, 1993; Eppinger, 1991; Koskela, 1997; Newton, 1995; Formoso *et al*, 1998; Mohsini, 1984; Mohsini and Davidson, 1992; Love *et al*, 2000) that interact and make it difficult to manage. Primarily, the process is iterative and poorly defined which can be attributed to two key factors. It requires the production of incomplete outputs to develop understanding of both design problems and alternative solutions and this is undertaken by a diverse team (e.g. Architects, Clients, Contractors, Mechanical, Civil, Structural, Electrical, Environmental and Process Engineers, Quantity Surveyors, Estimators and Planners) representing different disciplines, educational backgrounds and goals. As a result, the process is one of significant co-ordination, negotiation, agreement, and compromise often under uncertainty and time-pressure to achieve success. This can often result in changes, putting further pressure on the process and affecting progress and budget. Furthermore, if progress does falter then it can be difficult to get back on programme, as individual design tasks cannot be accelerated by introduction of additional resources. This is further compounded by the difficulty in determining progress of a process with the potential for iteration and yielding only negotiated solutions and no absolute answers.

Poor design process performance has a significant effect on the performance of subsequent activities and the finished product. The cause of the majority of construction delays and defects can be traced back to poor design process performance (Josephson, 1996; BEDC, 1987), with poor information alone creating problems more significant than those attributed to poor workmanship and site management. This can be attributed to the difficulty in controlling the nature of the design process (Baldwin *et al*, 1999). Therefore, the complexity and uncertainty of the construction design process requires the application of significant management effort (Newton, 1995; Gray and Hughes, 2001) for project success.

1.1.2 Design Management

Design Management is an emergent professional discipline which separates the management function of a project's design phase from the design function. It is becoming increasingly important in modern construction projects (Gray and Hughes, 2001). It is closely aligned to project management, it must provide a fully co-ordinated design, on time, meeting all stakeholder needs and it does this by co-ordinating, controlling and monitoring design activities while interfacing with other project and external parties. It is a task typically carried out by a design manager or team of managers depending on a project's size and complexity. However, Gray and Hughes (2001) suggest that while there needs to be a single point of responsibility to control the production of construction information they also believe DM is the responsibility of the whole project team.

1.1.3 Problems with Current Design Management Practices

Considerable advances have been made in DM, but there are still few examples of total success (Gray and Hughes, 2001). Current practice is characterised by poor communication, lack of adequate documentation, deficient or missing input information, poor information management, unbalanced resource allocation, lack of co-ordination between disciplines and erratic decision making (Austin *et al*, 1994; Cornick, 1991; Hammond *et al*, 2000; Koskela, 1997; Lafford *et al*, 1998). This in part can be attributed to the complex and challenging nature of the design process. However, many current approaches are inappropriate for managing the design process. For example, the design process is typically unstructured which leads to insufficient understanding of the design process between parties (Karhu and Lahdenpera, 1999) and is a barrier to people working effectively together (Taylor, 1993). The following outline the key problems and causes of poor DM practice.

Design planning

An effective and workable design programme is essential to improve co-ordination between disciplines and exert managerial control over the design process (Austin *et al*, 1994). Yet it is usually programmed to achieve the required timings of information release to contractors, followed by the preceding procurement activities and finally the design (Austin *et al*, 1998). This low priority of design in project planning is attributed to construction accounting for the majority of the project costs. However, there is now an increasing recognition that construction efficiency and costs are heavily dependent on the quality of the design solution and information (Austin *et al*, 1998) and therefore the quality of the design programme. Yet, little effort is given to planning the design in detail in the belief that it is not possible for such a creative and iterative process (Cole, 1993) - a situation perpetuated by a lack of understanding of design information flow, dependency and availability of suitable planning techniques (Austin *et al*, 1996).

Newton and Hedges (1996) claim that a poor understanding of information flow and dependency exists because each discipline does not understand how their work contributes to the whole building design process, causing a fragmented approach to planning. Therefore, the identification and co-ordination of cross-disciplinary information, essential for a fully integrated design, is left to the expertise of the design planner or project manager (Baldwin *et al*, 1994) who lack a full understanding of the processes of design (Hedges *et al*, 1993; Saxon, 1998). This results in a poor quality design programme with implications for the co-ordination of design disciplines and general process control.

Another facet of poor design planning practice is that resource allocation is often unbalanced (Cornick 1991, Austin *et al* 1994, Koskela *et al* 1997). This initially can cause delays (Koskela *et al* 1997b; Love *et al*, 2000) but can also escalate into further problems. In an attempt to retrieve delays, new designers are usually recruited, introducing additional delay, as they become familiar with project characteristics, requirements and history. This may in turn increase design error and subsequent time consuming rework (Love *et al*, 2000).

Integration of design and construction
A construction project involves a large group of people with different skills, knowledge and interests working together for a short period and then separating upon completion of the project. This creates problems in organising both the design and construction processes, due to the large number of interfaces and communication difficulties (Kagioglou *et al*, 1998). However, integration during the design phase is crucial to project success. It prevents problems in subsequent phases, it is necessary for the development of suitable design solutions (Mitropoulos and Tatum, 2000) and ultimately to achieve client satisfaction (Ferguson and Teicholz, 1992). Therefore, while it is clear that the integration of design and construction is vital to project success – it is also a fundamental weakness in the industry (Egan, 1998).

The distinct background, culture, learning style and goals of each category of construction professional is likely to cause adversarial positions (Powell and Newland, 1994; Kalay *et al*, 1998) with competition based on values associated with each party's speciality (Ballard, 1999). Yet this is exacerbated by each discipline focusing on its own processes with little energy on the development of the whole project process (Karhu and Lahdenpera, 1999). This has led to a growing misunderstanding of the role of each profession (Alshawi and Underwood, 1996) and many integration problems (Karhu and Lahdenpera, 1999) with eighteen different problems identified by researchers (Anumba & Evbuomwan, 1996; Mitropoulos and Tatum, 2000; Alarcon & Mardones, 1998, Kagioglou *et al*, 1998). Amongst the most significant are: lack of value for money for clients; increased design time and cost; sub-optimal solutions; lack of true project life cycle analysis; late design changes; and litigation. Therefore, integration of design and construction is a key improvement issue if the industry is to deliver advances demanded by Government task forces (Latham, 1994; Egan, 1998; Urban Task Force, 1999).

Information management
The principal design activity of any project is the processing of information (Baldwin *et al*, 1994; Heath *et al*, 1994), yet in the construction industry this is poorly performed (Latham, 1994; Kagioglou *et al*, 1998). Current management of design information is predominantly through schedules (Ballard, 1999) programmed to achieve the required timings of information release to contractors (Austin *et al*, 1998). Yet it does not consider the internal logic of the design process – such poor planning practice is a factor in poor information management (Formoso *et al*, 1998). As a result, the timing of information transfer is not properly controlled, designers do not have the right

information at the right time and are overloaded with unnecessary information (Huovila, 1997). This creates the risk of failure of design tasks, deficient analysis and wrong decisions with potential for waste in the process due to rework (Huovila *et al*, 1997; BRE, 1995; O'Brien, 1997; Frankenberger & Badke-Schaub, 1998). Furthermore, the erratic delivery of information and unpredictable completion of prerequisite work can quickly result in the abandonment of design planning (Koskela *et al*, 1997), therefore perpetuating a cycle likely to create further difficulties. As such information management is another issue vital to project success where the industry performs poorly.

Design Changes

Design changes are a significant problem in the construction industry. They have large administration costs (Machowski and Dale, 1995), account for 40-50% of a designers total work hours (Koskela, 1992) and even in well-managed projects can cost between 5 and 15% of total construction costs (Morris *et al*, 1999; CIDA, 1994; Burati *et al*, 1992). Love *et al* (2000) highlight that such costs could be even higher as they do not represent the latent and indirect costs and disruption caused by schedule delays, litigation costs and other intangible aspects such as buildability (Kagioglou *et al*, 1998). However, evidence suggests that even for successful, well-managed projects carried out by industry leaders, around two-thirds of design changes by cost are avoidable (Morris *et al*, 1999). This is a significant potential for improvement – so why is controlling change such a problem?

Newton and Hedges (1996) observe that traditional DM techniques cannot predict the effect of change on the design programme and fees. As such, it is difficult to determine all the possible change paths and to select which one of them is the best to follow (Mokhtar *et al*, 2000). Thus, if current tools cannot determine the full impact of design changes and human judgement is unable to account for the myriad interactions that jointly determine its outcome (Richardson, 1991; Sterman, 1992) then many design changes are being made without full exposure to all potential impacts. Such an inability to predict the impact of changes must be considered a barrier to effectively controlling design changes and therefore managing the design process. As such, if changes can be better controlled then there is more chance of project success.

1.2 CONTEXT OF THE RESEARCH

1.2.1 Problem Definition

Traditionally architects and engineers have dominated projects, with architects typically holding the primary position of authority in the design process. (Gray and Hughes, 2001). However, the construction industry has entered a period of rapid and irreversible change. New legislation, new Government guidance, new alliances, new working practices and new attitudes have all begun to change the way construction projects are formulated, designed and built (Spence, 2001) and have thus eroded the dominance of the architects and engineers.

Change has come about largely as a result of clients expecting better performance from the industry (Gray and Hughes, 2001), making increasingly exacting demands in terms of time, cost and quality (Austin *et al*, 1994; Koskela 1999, Songer *et al* 2000, Strassman 1995, Tluazca and Daniels 1995). Government task forces on both urban design (Urban Task Force, 1999) and construction (Latham, 1994; Egan, 1998) have stated that to meet such demands there needs to be step change in the way the built environment is designed and delivered, and part of this change requires design, procurement and construction to be an integrated process (Egan, 1998). As D&B type projects are seen as a means to integrate design and construction (Moore and Dainty, 1999) such procurement strategies have become widely used in recent years (Franks 1992; Marshall 1992; Akintoye, 1994; McLellan, 1994, Lafford *et al*, 1998). This trend is unlikely to falter. The UK Government, as a major industry client, now assumes that some form of D&B procurement will be used on its projects unless a compelling case can be made for using a traditional procurement route (Office of Government Commerce, 2002). Furthermore, recent targets set by the Strategic Forum for Construction aim to increase the use of integrated project teams and supply chains to 50% of projects (by value) by the end of 2007 (Egan *et al*, 2002).

The profitability of contractors from their normal contracting business has come under great pressure in recent years and many have made major public statements committing to reducing or indeed removing their involvement in traditional contracting in favour of exclusively negotiated or “partnered” projects (Cockshaw, 2001). This move away from traditional procurement routes has found contractors with an increasing responsibility for control of design - a process which they do not understand fully (Saxon, 1998) and have had little experience in managing. Yet design is crucial to project success (Morris *et al*, 1999; Cockshaw, 2001; Treasury Task Force, 2000) and poor performance can significantly affect project performance (Josephson, 1996, BEDC, 1987), therefore, as it is their profit and risk they must adapt accordingly. The learning curve is steep not least because many projects must now be delivered fast track while co-ordinating more specialists (Gray and Hughes, 2001) in the design of increasingly complex fabric (Austin *et al*, 1996) and content of buildings. While historically, design was manageable with simple planning and management techniques, Gray and Hughes, (2001) and Baldwin *et al* (1999) note that such approaches to DM are now inadequate as they have not evolved at the pace of industry changes.

As one of the contractors with an increasing interest in D&B, Private Finance Initiative (PFI) and Public Private Partnership (PPP) projects the sponsor needed to improve its DM performance. It needed to identify and develop approaches and tools capable of managing the construction design process and get them adopted in the organisation. This required the existing company culture to change (Burnes, 1996) and significant employee commitment (Kettley, 1995; Heppenstall and Lewis, 1996). Organisational change is a difficult process, exacerbated in this case by the condition of many current tools. As well as requiring modification to be able to manage current projects they were also fragmented, insufficiently developed, poorly deployed, couched in abstract terms (Freire and Alarcon, 2000; Frost, 1999), overly complex and force practitioners into unwanted discipline (Kanter, 2000). Properties that were unlikely to promote adoption amongst practitioners and such implementation barriers needed to be addressed.

Therefore, the research programme was to identify tools and practices, develop them to overcome implementation barriers, while making them capable of managing the design process and launch them to improve DM practice within the sponsor. Ways of overcoming and removing impediments to change are key to implementing change within organisations (Egan, 1995). Therefore, developing implementation strategies in the construction industry would add to this debate.

1.2.2 Design Management Research

The increase in interest in improving and researching DM has been relatively recent. The design process has been one of the most neglected areas in construction projects (Koskela *et al,* 1997). Austin *et al* (1993) reported that as there were clearer and more realisable benefits by improving performance on site, both in terms of management and construction techniques, much of the focus of industry research over the last two/three decades has been dedicated to this area. Therefore, as design only accounts for 3-10% of the total project cost, the greatest financial savings can be made by concentrating on construction efficiency (Edlin, 1991). Others have said that design has historically been ignored because the developer or contractor sees the investment in design as risk capital (Heath *et al*, 1994) or “out of pocket” expense, compared to the leveraged borrowings which finance the project proper (Bon, 1989). However, the relatively small cost of design to construction belies its true importance (Newton, 1995).

The increasing industrial and academic interest in DM is demonstrated by recent collaborative projects. These have focused on design planning and controlling change (Austin *et al*, 1998), control of design activities (Ballard and Howell, 1998), managing the integration of teams during the design phase (Austin *et al*, 1999; Austin *et al*, 2001; Business Round Table, 2002) and collaborative working (Steele *et al*, 2001).

Therefore, while there is much evidence and material to draw on in terms of current problems and issues there are few practices on which this research has been able to build. However, work by Austin *et al* (1999), Gray *et al* (1994), Gray and Hughes (2001), Cross (1989), Lafford *et al* (1998), Kagioglou, *et al* (1998) and Process Protocol 2 have influenced this research. This is discussed in detail in section 4.2.1.
While there is limited material that exists to draw on within the construction industry, other industries offer significant work for adaptation to construction. Lean Production and Concurrent Engineering are initiatives from the automotive, manufacturing and aerospace industries which hold valuable lessons for managing the construction design process as they address many of the problems outlined in 1.1.3.

Lean production was born out of the International Motor Vehicle Programme (IMVP) and focuses on removing waste from the process of vehicle manufacture (Womack *et al*, 1990) by examining all processes involved. It has five central interlocking ideas with which to examine these processes and establish lean production: specify value; identify the value stream; create continuous flow; organise customer pull; and pursue perfection (Womack and Jones, 1996). Useful tools have been developed from these principles to help implement lean in practice. These include Lean Supply Chain Management which co-ordinates all firms along the value stream (Womack and Jones, 1996), Value Steam Analysis and Mapping (VSAM) which aims to create lean business processes (McManus, 2002) and Just–in-Time Manufacturing (JIT) where equipment, resources and labour are made available only in the quantities and at the time required for the job (Galhenage, 1994).

While initial implementation effort has been in manufacturing, the Lean Aerospace Initiative was launched in 1993 and followed by the UK Lean Aerospace Initiative (UK LAI) in 1998 to develop and implement lean practices in their respective industries. To date there have been some notable successes in the implementation of lean in the aerospace industry (Squeo, 2000; Lewis et al, 2000; Cook, 2000).

Concurrent Engineering (CE) is a New Product Development (NPD) model particularly relevant to the construction design process as it focuses on the simultaneous development of design and manufacture. It is a systematic approach to the integrated, concurrent design of products and their related processes. It forces the product developers to consider all elements of the product life cycle from conception through disposal. (Dean, 1996) and involves designers and manufacturers working together to achieve common goals (Sheath *et al*, 1996). Concurrent Engineering is supported by several tools and techniques, some of which are relevant to the construction design process. These are Design for Manufacture and Assembly (DFMA) (Boothroyd and Dewhirst, 2003), Quality Function Deployment (QFD) (Rosenthal and Tatikonda., 1992) (also used as part of Lean Production) and Failure Mode and Effects Analysis (FMEA) (Ford automobile company, 1988).

The ideas and practices within Lean Production and Concurrent Engineering possess useful guidance for improving the DM process in the construction industry. However, the construction environment is significantly more complex than manufacturing, automotive and aerospace industries and consequently such innovations require more development to be implemented successfully (Marosszeky & Karim, 1997). This work is clearly underway with several recent projects to implement lean practices in construction (Bogus *et al*, 2000; Howell and Koskela, 2000; Common *et al*, 2000) and design (Melhado, 1998; Koskela *et al*, 1997; Miles, 1998; Austin et al, 2001). As none of the specific tools from Lean Production and Concurrent Engineering were ideally aligned with the needs of the research, it has instead drawn the ideologies of elimination of waste, concurrent working and the alignment of the design supply chain from those initiatives.

1.3 INDUSTRIAL SPONSOR

The industrial sponsor comprises two companies within the Skanska Construction Group: Skanska Integrated Projects (SIP) and Skanska UK Building (SUKB). They were recently a single company but during the course of the research began to focus on different market sectors. Skanska Integrated Projects focuses on capital work projects in Design & Build, Private Finance Initiative (PFI), Public Private Partnerships (PPP) and Prime Contracting. Skanska UK Building focuses on traditional contracting, but also undertakes some D&B work. For the remainder of this discourse they will be referred to collectively as the sponsor unless stated otherwise.

The sponsor recognised that the UK construction market was changing and considered there was the opportunity to improve project performance by addressing management of the design process. The sponsor's belief in the importance of this research to its operations is demonstrated by a public commitment (NCE, 2002) to deliver the training initiative to 600 employees. SIP is likely to derive the most benefit from the research in its project contractor and design manager roles. However, SUKB will accrue some learning for its D&B work and contracting role as it shares many issues with SIP of dealing with clients, designers and design subcontractors.

During the course of the research Skanska Integrated Projects and UK Building have provided funding, in kind support at workshops, for questionnaires and interviews as well as taking part in pilots of training, tools and techniques on projects.

2 AIMS AND OBJECTIVES

2.1 AIMS

It was considered during the early project stages that the research scope needed clearer definition. Specifically, this was to address two factors: an initial lack of understanding of the "state of the art" of DM research and the critical issues to address within the sponsor. With these factors in mind it was decided to divide the research into two phases.

Phase 1: initial investigation to establish a framework of appropriate research activities that could provide a significant contribution to the DM activities of the sponsor.

Phase 2: undertake a research programme to provide a significant contribution to the DM activities of the sponsor.

The aim for the delivery of phase 1 was:

Aim 1: ***To investigate how to improve design management processes and systems in the sponsor***

The outcome of phase 1 formulated the aim for Phase 2:

Aim 2: ***The identification and removal of barriers to the successful deployment of design management tools and techniques within the sponsor***

Broadly speaking Phase 1 was undertaken during the first year of the EngD Programme and the second, third and fourth years have been concerned with Phase 2.

2.2 OBJECTIVES

2.2.1 Phase 1 Objectives

The objectives to realise aim 1 within Phase 1 of the research were:

Objective 1.1 ***To understand current Design Management practices in the sponsor***

Objective 1.2 ***To establish the presence and significance of knowledge gaps in Design Management processes and systems as applied in the sponsor***

Objective 1.3 ***To develop a research programme into selected knowledge gaps in Design Management***

These objectives address the needs of Phase 1 by identifying the practices and tools appropriate to manage the design process, establishing where the sponsor needs to improve and combining them to formulate an effective future research programme.

2.2.2 Phase 2 Objectives

Following phase 1 there was a concern that the sponsor had insufficient DM maturity to immediately implement some of the practices and tools identified. This was addressed by deciding to deliver the research in two stages: The first stage would include the simpler practices and tools that could be implemented immediately and the second stage would be launched once it was considered that the sponsor's DM maturity had improved sufficiently. This led to objectives for each group of practices and tools ("existing" and "new") and guided the research for several months. However, a review of the initiative in the third year of the research illustrated that a staged approach was unnecessary and all suitable practices and tools could be launched together. Therefore, the "existing and "new" objectives were combined into a single set to guide the training initiative's development and an additional set established to control investigation into design process performance measurement. Further explanation of the reasoning behind this decision is provided in 4.2.3. The Phase 2 objectives were:

Objective 2.1: ***to identify appropriate design management tools to employ within the sponsor***

Objective 2.2: ***to prepare education training, implementation materials and documents for design management tools***

Objective 2.3: ***to review suitability of training and tools for application in the sponsor***

Objective 2.4: ***to successfully disseminate and educate sponsor's staff in the application of design management tools***

Objective 2.5: ***to review the application of design management tools and identify resulting improvements in design management practice***

Objective 2.6: ***to identify and overcome barriers to implementing design management tools***

Objective 2.7: ***to identify and prepare appropriate performance measurement techniques to employ within the sponsor***

Objective 2.8: ***to review suitability of performance measurement techniques for application in the sponsor***

These objectives address aim 2 by exposing the sponsor to new DM tools while allowing staged feedback to understand the impact of the tools on the sponsor, the performance of the implementation strategies and the effect of barriers on the success of the tools.

3 METHODOLOGY

Defining the appropriate research methodology to be implemented deals with four key issues (Phillilier *et al* in Yin, 1984): what questions to study; what data is relevant; what data to collect; and how to analyse the results. In addressing these questions it is necessary to explore the advantages and disadvantages of the five commonly utilised research strategies (Yin, 1984) and a sixth, Modelling, suggested by Steele (1999) as shown in Table 3.1. As can be seen in the table, strategy selection depends upon three conditions: The type of research question; the control of the investigator over behavioural events; the focus on contemporary phenomenon (Steele, 1999).

Strategy	Form of Research Question	Requires Control over Behavioural Events	Focuses on Comtemporary Events
Survey / Questionnaire	Who, what, why, where, how many, how much	No	Yes
Case Study	How, why	No	Yes
Modelling	Who, what, how many, how much	No	Yes / No
History	How, why	No	No
Archival Analysis	Who, what, why, where, how many, how much	No	Yes / No
Experiment	How, why	Yes	Yes

Table 3.1 Research Strategies Applicable to Design

In this study the richness of contemporary data was paramount to help understand the complexity of the research problem. Therefore, strategies that were able to collect data on many facets of an issue were vital. Survey/Questionnaire, Modelling and Archival Analysis are potential methods. However, Modelling was considered inappropriate, as it was not able to capture the “why” or “where” questions. Also, a brief review of the sponsor’s archive material showed that Archival Analysis would not be appropriate as the available material would not be able to focus on contemporary events or provide the richness of data required.

It was also considered likely that later in the study some form of implementation exercise would be appropriate. As it was not necessary to control behavioural events Experiments were not required. However, the Case Study approach was considered appropriate as it allows an empirical enquiry to investigate contemporary phenomena within real life criteria (Yin, 1984).

Therefore, principal investigation methods within the Survey/Questionnaire and Case Study strategies were appropriate to the research question. These are literature review, research interview, questionnaires, workshops and case studies.

3.1 PHASE 1 METHODOLOGY

The methodology devised to meet the Phase 1 objectives comprised: literature review; semi-structured interviews; and triangulation of interview results and literature.

3.1.1 Literature Review

The literature review served three purposes. It investigated underlying principles and themes of the construction design process and DM to provide an in-depth understanding of the process, practices, tools and issues. The review also provided an up to date assessment of the current maturity and direction of DM research and identified a framework of topics for the formulation and execution of the semi-structured interviews. The methodology is also discussed in Paper 1 Section 4.

3.1.2 Semi-Structured Interviews

A variety of techniques could have been used to collect data relating to the sponsor's DM practices and challenges. Questionnaires and structured interviews were inappropriate as investigations can be inadvertently narrowed and biased by the author's field of knowledge and lack the flexibility to probe issues not anticipated by the researcher. Workshops have flexibility, but can be biased by strong personalities and constrained by the effect of hierarchy amongst workshop attendees. They are also not particularly useful for identifying the individual experience. Unstructured interviews can be useful for controlling bias. However, results can often be difficult to code and analyse. As the interview focus was well understood: "Understand DM challenges and issues in current practice", they were considered unnecessary. However, to avoid biasing the results, a degree of flexibility was needed to allow areas of interest to be probed as they arose during the interview. Therefore, semi-structured interviews were seen as the most suitable means to collect this data by allowing a degree of flexibility and focus.

To mitigate weaknesses of research interviews, authoritative texts (Brenner *et al*, 1985; Brenner, *et al*, 1981; Steele, 1999) were consulted in formulating and executing the research interviews and discussions were held with Steele to understand interviewing within the context of engineering design research. Detailed planning of the questioning was undertaken to ensure that it covered all areas of DM; did not collect irrelevant information; was clear, unambiguous and unbiased. Finally, a pilot interview was undertaken to ensure responses were adequate, that interview time was reasonable, that probing was employed appropriately and to allow practice in the recording methods. This pilot was followed through to data presentation to ensure that all stages of the research and analysis process was thoroughly checked. Further details are in Paper 1 Section 4.

All interviews were undertaken on a one-to-one basis in a private office to avoid any interruptions. A combination of audio taping and written record was used during each interview. The former to ensure all comments were captured and the latter to note particular issues and to ensure interviews covered the subject area in sufficient detail. All data was then transcribed to aid clarity and consistency of later analysis. Before coding proper took place it was necessary to edit the data as set out by Moser and Kalton (1971) to check for completeness, accuracy and uniformity. The coding of the transcribed data took care to ensure the results were easy to use and understand and at an appropriate level of detail.

3.1.3 Triangulation of Interview Results and Literature Review

A significant potential weakness with the interview results was that they were only relevant to the sponsor and not the general construction community. Therefore, to address this Triangulation of the interview results with knowledge obtained from literature was used. Literature findings were mapped against the interview results to confirm these as valid DM issues common to the industry and not merely the sponsor. From this it was also possible to map against the DM issues their root causes and appropriate improvement mechanisms identified in literature to understand potential solutions to the problems facing the sponsor and the general construction community. Finally, current projects in DM were mapped against the improvement mechanisms to establish where to focus the research to provide competitive advantage to the company while ensuring it did not duplicate any existing work. Further detail of this exercise is discussed in Paper 1 Section 4.

3.2 PHASE 2 METHODOLOGY

The methodology to meet Phase 2 objectives comprised a state of the art review; questionnaire; structured interviews; review workshop; DM maturity assessment, semi-structured interviews; a case study and a review of sponsor's project management systems.

3.2.1 State of the Art Review

The state of the art review continued the development in understanding the research domain and the barriers that must be addressed. This was expanded to encompass organisational change literature (Paper 2 Section 3) to help guide the strategy and content of the initiative and performance measurement literature (Paper 5 Section 2) to inform the investigation into design performance measurement. It also revealed source material from which practices and tools were developed for the training initiative and guided the format of the initiative by identifying similar work (Austin *et al*, 2001; Thomson and Austin, 2001).

3.2.2 Review Workshops

Three workshops were used throughout Phase 2. Review Workshop 1 was carried out with a sponsor appointed improvement team to assess the format, content and delivery of the training initiative. The methodology is discussed in Paper 3 Section 2.

Workshops 2 and 3 were held with a new improvement team nominated by the sponsor's new management team brought in part way through the research programme. Further details of the implications of this are provided in section 5.6. Workshop 2 was used to establish how well employees were receiving the DM Handbook and Detailed DM Training to determine if any modifications were necessary. This was done by reviewing comments made on training feedback forms about the Handbook and Training content. Review Workshop 3 was similar to Workshop 2 but assessed the Awareness Training by reviewing training feedback forms. Review workshops were an appropriate method, as decisions had to be quick and collective, and analysis of questionnaires or interviews would have significantly slowed the development of the training initiative.

3.2.3 Questionnaires

A questionnaire was issued to Workshop 1 attendees after the workshop to collect more detailed views on the content and delivery of the training initiative from individual attendees. The methodology is discussed in Paper 3 Section 2.

A structured questionnaire was also used to elicit attendee's views on the content and delivery of the DM Detailed Training and DM Awareness Training. This was a standard questionnaire used by the sponsor to test training courses it offers. However, it was reviewed using guidelines (Race, 2001; Fellows and Liu, 1997) to ensure it followed good practice.

3.2.4 Structured Interviews

Structured interviews were used to establish which of the 46 employees exposed to the training initiative as part of a pilot study had used the DM Handbook practices and tools. This identified who was to be interviewed in more detail and established why others did not use the Handbook and their views on the Awareness Training. The methodology is discussed in Paper 4 Section 2.

Structured interviews were also used during the development of Design Process Performance Indicators (DPPIs). They were used to establish what practitioners have used to monitor design process performance, what they would like to use to monitor design process performance, and ultimately how useful they considered the suite of DPPIs for monitoring design process performance. The methodology is discussed in Paper 5 Section 2.

3.2.5 Design Management Maturity Assessment

The maturity assessment used a Design Management Maturity Model to establish the change in DM maturity throughout the company caused by the training initiative. Its development and use are explained in Paper 4 Section 2.

3.2.6 Semi-Structured Interviews

Semi-structured interviews were used to capture the impact of the practices and tools presented by the training initiative on individual and project performance, the difficulties people had in applying the practices and tools. The considerations for choice of this method and preparation and execution were similar to those explained in 3.1.3. The views on the DM Handbook, the Awareness Training and DM on the sponsor's IMS were also sought. The methodology, coding and analysis of interview data is explained in Paper 4 Section 2.

3.2.7 Case Study Investigation

The case study was undertaken to help understand at first hand the issues and barriers to deployment of DM practices and tools. This was done by supporting a project team in the implementation of the practices and tools contained in the Handbook. The methodology is discussed in Paper 4 Section 2.

3.2.8 Review of Project Management Systems

The review of the sponsor's project management systems was used during the investigation of DPPIs. Paper 5 Section 2 discusses the methodology.

4 RESEARCH ACTIVITIES AND FINDINGS

The main activities over the four years of the research programme are explained in this section. It outlines how tasks were formulated to address aims and objectives and shows how other research and sponsor requirements influenced the research. It also describes the findings and decisions made during the programme. The whole process, in terms of activities, findings, decisions and outputs is summarised in the Research Development Map (Figures 4.5 to 4.10 in Section 4.7). This illustrates the research progression emphasising how findings and decisions resulting from activities were used to influence subsequent investigations as well as highlighting when objectives were realised and programme deliverables produced.

4.1 THE RESEARCH PROBLEM

The activities to establish a clear understanding of the research problem covered Phase 1 (Figure 4.6) and formulated the activities for Phase 2. These are discussed in Paper 1 Section 7, it is recommended that the whole paper be referred to at this stage.

4.1.1 State of the Art of Design Management

The investigation of current literature identified underlying principles and themes of the construction design process and DM as well as providing an in-depth understanding of the process, practices, tools and issues. This was focused on achieving objectives 1.2 and 1.3 by establishing the general performance of the industry as well as identifying the practices that the sponsor should and can apply. The review also provided an up to date assessment of the maturity of DM research and identified a framework of topics for the formulation and execution of the semi-structured interviews.

It established the importance of the design process to the success of each project (Morris *et al*, 1999; Cockshaw, 2001; Treasury Task Force, 2000; Prescott, 1999) and that poor performance in the design phase can have serious consequences for subsequent activities and the finished product (Josephson, 1996, BEDC, 1987) but its very nature makes it difficult to manage. The complexity and uncertainty associated with the iterative nature of the process (Koskela, 1997; Newton, 1995; Formoso *et al*, 1998), the large volume of information and the different goals and values of the many project stakeholders (Mitropoulos & Tatum, 2000) requires significant management effort to control. It also established the potential that design changes have for significantly affecting progress and budget (Love *et al*, 2000).

The review also determined that current practices are outdated following significant industry changes – not least the drive to improve time, cost and quality of the finished product (Austin *et al*, 1994; Koskela, 1999; Songer *et al,* 2000; Strassman, 1995; Tluazca and Daniels, 1995) and such practices are finding it difficult to manage current projects. Specifically, it identified the poorly defined and unstructured design process (Karhu and Lahdenpera, 1999), approaches to design planning (Austin *et al*, 1999), lack of integration between project parties (Egan, 1998) and poor information co-ordination (Latham, 1994; Kagioglou *et al*, 1998) as key factors in inadequate management of the design process. Furthermore, it established that the format of many current tools makes them difficult to deploy in practice (Freire and Alarcon, 2000; Frost, 1999).

4.1.2 The Sponsor's Design Management Practices

Semi-structured interviews carried out throughout the company to understand the sponsor's DM performance and maturity, to address objective 1.1 by developing an understanding of the sponsor's DM practices. The exercise identified 35 separate problems with managing the design process across the sponsor and established that it lacked a structured DM approach and subsequently a consistent platform of DM practices to manage projects. This was seen as a barrier to improvement as to manage a process effectively it must be repeatable (Hinks *et al*, 1997) and such an inconsistent approach was making DM difficult and preventing learning that could deliver process improvements. However, until these findings were considered against literature based evidence it was not possible to decide on an appropriate and clear improvement programme.

The mapping of issues and problems reported in literature against those experienced by the sponsor validated interview results and confirmed that the sponsor was experiencing common industry problems. The exercise was focused on achieving objective 1.2 by identifying the processes that the sponsor should improve to address its DM problems and objective 1.3 by establishing the Phase 2 strategy. Improvement mechanisms (strategies that address DM problems and issues) identified in literature were also mapped against these issues to establish mechanisms that were most appropriate to deploy across the sponsor. This also ensured that any improvement actions and subsequent findings would be widely applicable to the industry and not just the sponsor. The methodology employed is explained in detail in Paper 1 Section 4. A cluster of six improvement mechanisms was identified by this exercise to address the major and majority of DM issues facing the sponsor. These were:

- Structured and Explicit Design Process
- Improved Design Planning
- Integrate Design and Construction
- Information Flow Management
- Understand / Predict Impact of Design Changes
- Feedback System

The sponsor decided to pursue the provision of a Feedback System centrally, therefore focusing the research effort on the other five improvement mechanisms. The results of this exercise also illustrated that while some improvement mechanisms were more fundamental to improving DM than others they were interdependent. Also, the mechanisms covered the core of DM activities and therefore to address all these issues the sponsor would have to redefine its whole DM approach. The research strategy was formulated with this in mind. This was to develop and deploy a training initiative to improve the sponsor's DM and is described by steps 1 to 7:

1. collect and compile literature on aspects of DM practice;
2. prepare training material and implementation strategies to deploy training initiative;
3. review training material for applicability to sponsor's operations;
4. revise training material for deployment;
5. deliver training initiative to improve DM practices;

6. establish use and impact of practices and tools on DM and project performance, identify further implementation barriers; and
7. prepare additional strategies to overcome further implementation barriers.

This approach was considered appropriate for a combination of reasons. The practices across the sponsor, like in the industry generally, were inconsistent, unstructured, and often inappropriate to manage current projects (Gray & Hughes, 2001; Freire and Alarcon, 2000; Frost, 1999; Kanter, 2000). Therefore, they required modification to suit the modern project. Also, employees would have to be involved in the formulation of the practices and tools to ensure commitment to the change in DM practices (Kettley, 1995; Heppenstall and Lewis, 1996). Furthermore, as improving DM practice within a design and construction organisation requires organisational change, the improvement strategy had to be long-term (Firth, 1999; Rapp, R., 2001; Williamson *et al*, 2001) and overcome a range of barriers, not least the underlying company and construction industry culture.

At this stage the sponsor requested that the research should primarily focus on the D&B sector. It is in such procurement routes where the sponsor has the most influence over the design process and it is a sector where like many of its competitors it had become increasingly involved, therefore offering significant potential for competitive advantage and profitability.

The improvement would be delivered using a training initiative of four complimentary approaches: A DM Handbook; DM Training; Team Support; and Project Monitoring. The DM Handbook would be the core of the training initiative. It provides guidance on critical aspects of DM practice and supporting tools. Training on practices and tools would be provided to project teams throughout the company. Project teams would be supported in the implementation of the new practices and tools through Team Support to help embed new ways of working in company practice. Project Monitoring would aim to establish the impact of the new practices on project performance to demonstrate that they are working and thus reinforce change.

4.2 TRAINING INITIATIVE DEVELOPMENT

The activities associated with the training initiative development were focused on developing practices and tools, the DM Handbook format and style as well as training workshops to deliver the practices and tools to the sponsor's employees.

4.2.1 DM Handbook

Initially it was necessary to identify practices and tools in line with the improvement mechanisms and then modify them to overcome barriers (Freire and Alarcon, 2000; Frost, 1999; Kanter, 2000). This exercise is explained in Paper 2, it is recommended that the whole paper be referred to at this stage.

The ongoing review of design process and DM literature was focused on addressing objective 2.1. It identified suitable practices and tools, for which the methodology is explained in section 3.2. The tools were modified by considering implementation barriers (Paper 2 Section 4) to address objective 2.2 and generated the core contents of the first draft of the DM Handbook (DM Handbook v1): ten chapters each covering a critical aspect of DM practice and accompanying 21 tools. It was prepared using Microsoft Word and imported pictures created in Microsoft PowerPoint as illustrated by Figure 4.1.

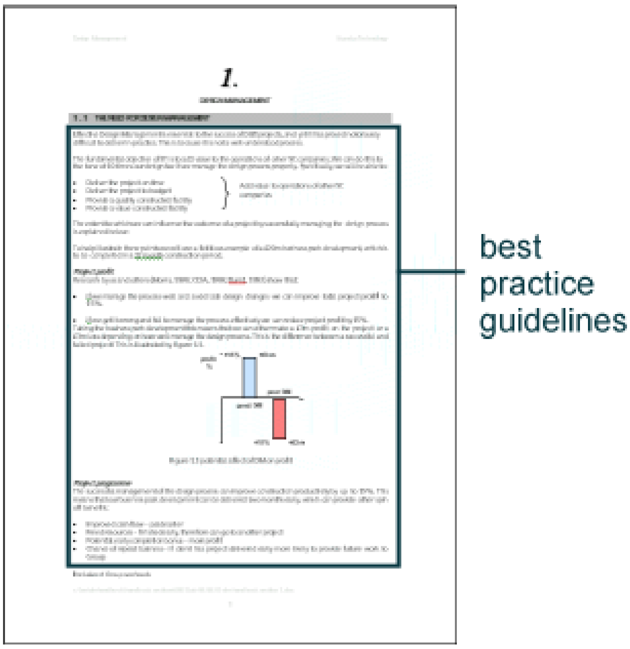

Figure 4.1: Handbook v1 Chapter Format

Many literature sources were used to develop Handbook v1 contents. However, there were some notable sources used to establish each of the 21 DM tools. The methodology for Master Design Programme was based on an approach considering design information flow (Austin *et al*, 1999). Strategies suggested by Austin *et al* (1999) to overcome difficulties caused by iteration were developed into Staged Information Delivery and Fix Information respectively. Ideas suggested by Gray *et al* (1994) and Gray & Hughes (2001) were used to develop Brief Document, Consultant Benchmarking and Consultant Interviews, Information Transfer Schedule, Work Package Document, Design Change Workshop and Interface Schedule. The roles and responsibilities of DM throughout the project process defined by Kagioglou *et al* (1998) and Process Protocol 2 as well as required design manager qualities (Lafford *et al*. 1998) were used to influence the general framework of Handbook v1. Value Analysis, Brainstorming, Decision Matrix, Task Force Meeting and Design Workshop were developed from ideas by Cross (1989).

Also identified at this stage were a set of potential tools that were considered too advanced for the sponsor and their launch should be considered once the training initiative had improved the sponsor's DM maturity sufficiently. These tools are shown in Table 4.1.

tool	source
Rapid Design Development	Scheme Design In A Day (SDIAD) by Miles (1998)
Design Management Process Model	Process Protocol II by Kagioglou et al 1998
Last Planner	Ballard and Howell, 1998
Design Process Performance Indicators (DPPIs)	-
Stage-Gate design freezes	Process Protocol by Kagioglou et al (1998)
Interface Schedule	Gray and Hughes, 2000
Discipline Design Programme	Austin et al, 1998
Last Responsible Moment (LRM) design freezes	Lane and Woodman, 2000

Table 4.1 “New” Design Management Tools for Future Implementation

The contents and format of Handbook v1 were reviewed to ensure practices, tools and their presentation were user friendly. It was established that the Handbook format was not particularly user friendly. The combination of associated tools and guidance in Handbook chapters was considered confusing. Furthermore, there was no clear indication of where tools should be used in the process. It needed a clearer structure and professional format to appeal to practitioners. Therefore, outputs of similar projects (Thomson and Austin, 2001; Austin *et al*, 2001) were consulted to help present the content in a user-friendly format. From this exercise, Handbook v2 was created: Ten chapters each covering a critical aspect of DM practice followed by tool selection tables (to help users select tools) and a toolbox of 21 DM tools. Table 4.2 shows the chapter contents and associated tools. To address the fragmented nature of tools (Friere and Alarcon, 2000) and ensure they were coherent and co-ordinated any synergies between tools were clearly indicated. To help practitioners identify where to use tools in the process they were categorised into four inter-related tool types: Planning; Co-ordination; Development; and Monitoring; and given a unique alpha-numeric reference based on these categories (e.g. Planning - P01, Co-ordination – C01, Development – D01, and Monitoring – M01).

handbook section		topics covered	tools provided	
1	Design management	The need for and what is design management? Nature of the design process Why current design management goes wrong How can we better manage the design process?		
2	The design process	Nature of the process Involve parties at the right time Allow adequate design time Engender common design process		
3	Stakeholders objectives, briefs and tasks	The need to, barriers to and incorporating stakeholder needs in the design	P01 P02 P03 P04	Brief document Concept design kick-off meeting Scheme design kick-off meeting Detailed design kick-off meeting
4	Managers and structures	The need for, barriers to, qualities of and training good design managers suitable organisational structure		
5	Selecting team members	Importance of the team, necessary relationships and attitudes, skills and competencies	P07 P08	Consultant benchmarking Consultant interviews
6	Planning the design process	The need for, barriers to and planning the design process	P06	Master design programme
7	Ensuring design delivery	The need for, barriers to and effective design delivery	C01 C02 C03 M01 M02	Information transfer schedule Work package document Co-ordination meeting Progress report Progress meeting
8	Managing information flow	The need for, barriers to and effective information flow management	C04 C05 C06	Design workshop Staged information delivery Fix information
9	Developing the design	Barriers to and the process of design development	D01 D02 D03 D04 D05	Value analysis Brainstorming Decision matrix Task force meeting Design guide document
10	Design changes	The effect of, barriers to and managing design change proposals	P05	Design change workshop

Table 4.2: Design Management Handbook v2 Contents

The format of chapter and tool pages was also standardised to make them accessible and relevant to the needs of practitioners by aiding reference, comparison and selection of tools. This is explained in Paper 2 Section 5. Figures 4.2 and 4.3 are examples of chapter and tool format.

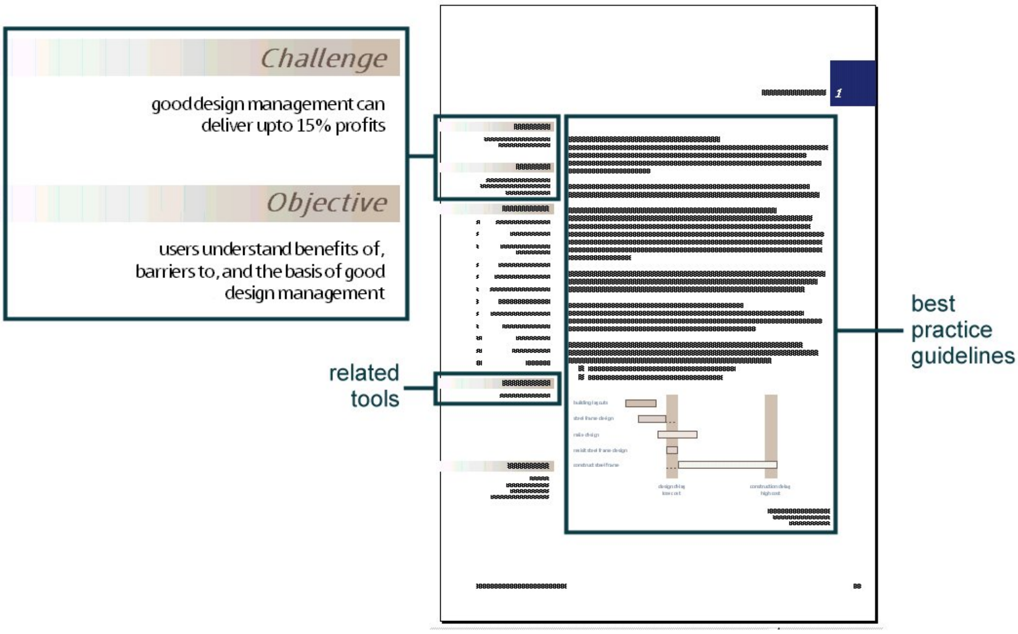

Figure 4.2: Handbook v2 Chapter Format

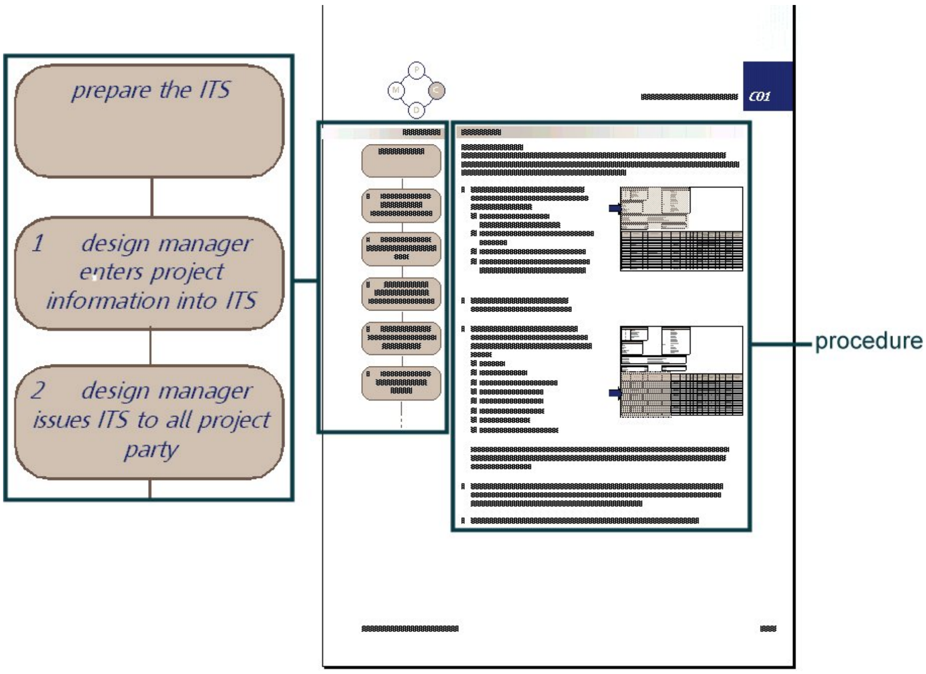

Figure 4.3: Handbook v2 Tool Procedure and Flowchart

4.2.2 DM Training

To deliver the contents of the DM Handbook v2 a Detailed DM Training programme (v1) was developed. It comprised a series of ten training workshops: each covering a specific DM topic, introducing best practice practices and associated tools. A key focus of the training was to engender amongst practitioners a consensus that the existing methods were no longer producing results – vital for organisational change (Filson and Lewis, 2000). This would be achieved by allowing attendees to identify the key problems they consistently face and then convince them that Handbook practices and tools are appropriate to their requirements by explaining how they were formulated to address these issues. In addition to this, attendees were asked to complete a DM Maturity Assessment developed for the research. Its development and methodological use is referred to in Section 3.2 and discussed in Paper 4 Section 2. The assessment was conducted for two reasons. The first was to highlight where practices were behind the state of the art and thus build consensus that current methods were outmoded and change is necessary. The second was to test the impact of the training on the perception of the sponsor's DM maturity. To achieve this, attendees completed the assessment immediately before and after the training session.

Another vital feature of the training was the interactive format. Attendees have the opportunity to discuss and become familiar with suitable practices and tools as well as influence the Handbook's future format and content by their comments. Such control over the process of organisational change (Mohamed, 1999) ensures that participants demonstrate significant commitment, which is key to a successful change programme (Kettley, 1995; White, 1979). Further details of Detailed DM Training are provided in Paper 2 Section 6.

Review Workshop 2 established that the training had too much detail for non-design manager attendees and was only relevant for design managers and others needing the detail of the practices and tools. The improvement team agreed that DM Awareness Training should be prepared to cover the key messages of Detailed DM Training v2, identify the benefits to each party from the changing practices and where they are involved (Pugh, 1993) to improve commitment to the change. The DM Maturity Assessment was well received in Detailed DM Training v2 and it was agreed to retain it for Awareness Training. Following these guidelines DM Awareness Training v1 was produced and launched across the sponsor.

The DM Awareness Training v1 was reviewed soon after its initial launch in Review Workshop 3 to establish whether the training was effective in generating commitment to the change programme and if any modifications were necessary. Generally, it was well received by attendees and appeared to address concerns that the Detailed DM Training was too detailed for some employees. However, it was expected to improve its explanation of how tools integrate other project operations. This modification was included in Awareness Training v2. Following the review and modifications to DM Awareness Training the research programme continued with the delivery of DM Handbook v3, Detailed DM Training v2 and DM Awareness Training v2 to the sponsor's projects.

4.2.3 Testing Training Initiative

Review Workshop 1 followed by an associated questionnaire was used to review the Handbook and Detailed DM Training for suitability to the sponsor's operations to address objective 2.3. The methodology is explained in Section 3.2 and the whole exercise is explained in Paper 3. It is recommended that the whole paper be referred to at this stage.

The improvement team concluded DM Handbook v2 and Detailed DM Training Workshops v1 were appropriate to the sponsor's needs by providing an understanding of the practices and tools that can help the sponsor improve DM. As the initiative was based on common industry problems and sponsor's needs it was concluded that it had potential to improve DM performance within a design and construction organisation as it provided a sound understanding of the issues surrounding modern DM and practical ways of managing the process.

The improvement team considered the majority of practices and tools appropriate for the sponsor's operations. The only tools deemed inappropriate were P07 Consultant Benchmarking and P08 Consultant Interviews in traditional contracting. This was addressed in DM Handbook v3 by highlighting the suitability of the tools for D&B (which includes PFI), novated D&B and Traditional procurement routes on each tool and the tool selections tables.

There were several requests in the workshop and in questionnaire responses to add to Handbook chapters and prepare additional tools, as shown in Table 4.3. All requested additions were developed and included in Handbook v3 apart from the 360° Performance Appraisals supported by a project database. The sponsor would pursue this as part of its development of its Feedback System.

handbook section	tools provided	training initiative improvement actions
2 The design process		Detailed model of design process activities Structured and explicit design management process
3 Stakeholders objectives, briefs and tasks	P01 Brief document P02 Concept design kick-off meeting P03 Scheme design kick-off meeting P04 Detailed design kick-off meeting	Tool to review / check the developed design will meet stakeholder requirements
4 Managers and structures		Detailed design manager job description
5 Selecting team members	P07 Consultant benchmarking P08 Consultant interviews	360 degree performance appraisals for all project parties supported by database of benchmarking data.
10 Design changes	P05 Design change workshop	Comprehensive design change management process

Table 4.3: Suggested Training Initiative Modifications

The launch date of the tools that were initially considered too advanced for the sponsor (see Table 4.1) was also considered during the Review Workshop 1. The implementation team considered that the sponsor had sufficient DM maturity to implement Stage-Gate design freezes (Kagioglou *et al* 1998), a modified version of Gray and Hughes' (2000) Interface Schedule and a Discipline Design Programme tool developed from a methodology proposed by Austin *et al* (1999). These tools were included in DM Handbook v3. They also considered that a DM Process Model modified to suit the sponsor's operations from Project Protocol 2 and Kagioglou *et al* (1998) would be a useful tool. It showed where DM tools should be used to support each DM activity during the design process as well as the involvement of all project parties in these activities. It was considered important to explain when to use the tools and allow project team members to recognise their design process responsibilities. This would be reproduced at the front of DM Handbook v3 and used as the primary navigation pages for the DM part of the sponsor's Integrated Management System on its Intranet. Further details of the Integrated Management System (IMS) are provided in 4.3.

The improvement team considered that the sponsor might be ready for Design Process Performance Indicators but that similar exercises within the company relating to construction performance indicators had not been particularly successful. Therefore, it was decided that further investigation was necessary to determine which DPPIs should be developed and how they should be designed to overcome implementation barriers.

LRM design freezes (Lane and Woodman, 2000) were considered too advanced for the sponsor, but the implementation of Stage–Gate design freezes would be monitored to determine the impact and thus whether LRM design freezes would be appropriate at a later date. The improvement team was interested in implementing Last Planner (Ballard and Howell, 1998), but in relation to all company operations and not just DM. Therefore, it was pursued centrally by the sponsor and removed from the research programme's scope. Rapid Design Development (Miles, 1998) was seen as a tool for the design team rather than the sponsor and therefore it was decided not to pursue the idea any further.

The improvement team's views negated original concerns that the sponsor had insufficient DM maturity to implement the "new" tools and this affected the Phase 2 strategy. Therefore, it was streamlined to implement all tools together.

A significant finding arising out of Review Workshop 1 was that the relatively low position of a design manager within the project team structure which was also noted by Heath *et al* (1994) could act as a major barrier to implementing the DM practices and tools in practice. Furthermore, it was noted that the actions of other project operations could have a significant effect on DM's success. Therefore, one recommendation was to elevate the design manager within the project team management structure to a comparable position of authority to other senior managers. However, this was the sponsor's long-term aim and the improvement team decided it was beyond the research scope primarily because it would have to address a major barrier over which it would have little control – the project power structure. This was recognised by Nadler (1993) as manifested by those in power resisting change because they feel threatened. It was considered that the sponsor would address this barrier at a later date. Therefore, the alternative approach was to involve all project parties in training to make the case for change more obvious to them (Pugh, 1993) to get them to buy into the change programme and thus overcome the barrier of other project parties influencing design process performance.

Reflecting on the improvement team's comments DM Handbook v3 and Detailed DM Training v2 were produced and launched throughout the sponsor to improve DM practices and to pilot the Handbook and Training.

When the new improvement team was established they were unfamiliar with the training initiative and decided to review it as the first team did. They were generally satisfied with its format and contents, but did request some additions associated with other disciplines activities during the design process. Commercial and procurement processes needed modification to be aligned with the new DM processes. Also a model designers' contract was identified as a necessary tool to standardise contracts across the business. However, the improvement team agreed to freeze the DM Handbook v3 for the remainder of the research programme to allow the practices and tools to be piloted. The practices would be added to the Handbook following the completion of the research.

4.3 DESIGN MANAGEMENT ON THE SPONSOR'S IMS INTRANET

To improve availability of the DM Handbook v3 tools, the sponsor decided to place the tools as part of an Integrated Management System (IMS) covering all operations on its Intranet. The DM Process Model modified from Project Protocol 2 and Kagioglou *et al* (1998) was used as the primary navigation tool from which each tool process and supporting documents (forms, schedules and spreadsheets) could be accessed. Figure 4.4 shows an extract from the DM Process Model.

process	activity	responsibility			involvement						tool
		design manager	design co-ordinator	document controller	designers	commercial	construction	planning	project manager	client	
resources	identify design capabilities and design management requirements	R					X		X	X	P10
	select and assemble design management team	R					X		X	X	no tool for this activity
	select and assemble core design team architect, struct, m&e, public health, fire, acoustic, IT/comms	R				X	X		X	X	P07 P08
	obtain information and knowledge for use in detailed / later phases codes/standards/best practice guides	R	D		X	X	X	X	X	X	no tool for this activity
	identify key team members for construction phase	R					X		X	X	P07 P08
plan	identify / review stakeholder requirements prepare brief document	R			X	X	X	X	X	X	P01
	plan communications strategy internal and external communication procedures, IT communication tools, distribution details	R	D		X	X	X	X	X	X	no tool for this activity
	review and update project scope and milestone dates update brief	R	D				X	X	X	X	P01
	prepare detailed phase master design programme integrate with procurement and construction	R	D		X	X	X	X	X		P06
	review discipline programmes	R	D					X			P09
	select phase review board prepare review agenda, send documentation to phase review board	R							X		no tool for this activity
	phase kick off meeting update all programmes, issue / review key phase, documentation, brief design teams	R			X	X	X	X	X	X	P02
	define design management procedures and tools to be used brief design team in use of tools	R									section 11 design management handbook

Figure 4.4: Extract from Design Management Process Model

As the research provided the basic content for the DM IMS, diversification into the development of the DM IMS was considered potentially time consuming and not associated with research objectives. It was agreed that the sponsor would take ownership of the DM IMS and allow the research to focus on other key issues. As a result the researcher had little involvement in its preparation and therefore influence over the presentation style and content. However, this was a useful exercise in addressing objective 2.4 by helping to disseminate the contents of the DM Handbook v3 to sponsor's staff.

The new improvement team reviewed the content and format of the DM IMS v1 in Review Workshop 3. It was concluded that it was difficult to navigate and this would prevent practitioners from using it. Furthermore, it should show links to other project processes. The improvement team member leading the IMS production agreed the modifications. However, as the IMS was still under development the primary task was to populate it with the sponsor's project operations and then consider improvements.

The interviews undertaken to establish the impact of the training initiative established that few used the DM IMS v2 as it did not provide anything in addition to the Handbook, access problems were experienced and many found navigation difficult, as identified by the improvement team.

4.4 APPLICATION OF TRAINING INITIATIVE

The DM Awareness training was delivered to approximately 600 employees throughout the sponsor's D&B, PFI and traditional contracting projects to educate them about better ways of managing the design process, how they are involved and ultimately achieve project team commitment to the DM change programme. A training team was formed: the researcher and another trainer delivered training to D&B and PFI projects while the other two trainers delivered to traditional projects. A copy of DM Handbook v3 was issued to each project following Awareness Training sessions. In addition each design manager and others who had expressed an interest (inc. project and planning managers) attended Detailed DM Training sessions and were each issued with a copy of the DM Handbook v3. These were key activities in disseminating an awareness of DM practices and tools to the sponsor's employees and thus to address objective 2.4.

The investigation and analysis of the training initiative's application across the sponsor related to objective 2.5 by establishing the impact of the initiative on the sponsor's performance and objective 2.6 by identifying whether the initiative had addressed implementation barriers. This investigation, results and case study investigation (4.5) are explained in Paper 4. It is recommended that the whole paper be referred to at this stage. Several methods were used to investigate the training initiative impact on projects: questionnaire; structured interviews; semi-structured interviews; and DM maturity assessment. These methods are explained in section 3.2 and Paper 4 Section 2.

The Handbook proved to be an effective means to disseminate DM practices throughout the sponsor. It was well received by interviewees once they had come to terms with its size (256 pages), with the overwhelming majority of design managers and even some other disciplines using its practices and tools. Furthermore, 30 out of the 39 practices and tools proved to be critical to DM by delivering critical benefits (related to time, cost and quality) – thus indicating that the training initiative has had a positive impact on project performance and therefore achieving its goal. Several interviewees considered the author's presence as the sponsor's DM champion improved DM performance by acting as an impetus for change. Furthermore, DM maturity assessment results suggested the sponsor had improved performance by almost a complete maturity level.

The maturity assessment proved to be a useful tool in changing DM practices by helping to create a consensus that practices needed to improve and by describing how practices need to change to achieve greater DM maturity. This was vital for the change programme (Filson and Lewis, 2000) as it reinforced the desired change (Galpin, 1996). It was a useful and simple to understand indicator for the improvement delivered made by the training initiative. For the sponsor it helped reinforce changes by providing a means to express improvements delivered and set the agenda for the next stage of improvement.

While the DM practices and tools consistently delivered critical impacts (a timely delivered design, a design meeting client requirements, a co-ordinated design and fewer late design changes) very few helped provide cost certainty of design. However, this was tempered by the fact that cost control is seen as a commercial task rather than a DM task. Nevertheless, it was considered necessary to establish what DM techniques and approaches are appropriate for effective cost control of the design product was defined as a focus of future research.

Interview comments highlighted that there were lost opportunities where improved DM performance was hidden by action (or inaction) of others. This supported Review Workshop 1 findings and illustrates the effect that departmentalising (as discussed by Womack and Jones' (1996)) has on sub-optimising the design process. To address this, the sponsor resolved to involve the whole project team, the client and the design supply chain in future DM Awareness Training and this will be delivered at project start up to get all parties to commit to the DM processes.

Three main types of barriers were identified: selection, pre-application and application barriers. Barrier descriptions are provided in Paper 4 Section2. Table 4.4 shows the different types of selection, pre-application and application barriers identified. They are ordered by their significance in each category and critical barriers are highlighted.

While selection barriers were disruptive when encountered, they rarely occurred, yet were good indicators of the DM suitability of practices or tools. However, pre-application and applications barriers were far more disruptive.

		Key: critical barrier (shaded)
selection barriers	responsibility of other management function	critical barrier
	does not help manage the design process	critical barrier
	not suited to D&B procurement route	
pre-application barriers	lack of leadership from senior management	critical barrier
	no agreed project design management process	critical barrier
	client ignoring design freeze / change control	
	inflexible construction programme	
	commercial decisions / lack of decisions affecting design	
	construction team ignoring design freeze / change control	
	inflexible client programme	
	parties not collaborating	
application barriers	lack of leadership from senior management	critical barrier
	construction team ignoring design freeze / change control	critical barrier
	client ignoring design freeze / change control	critical barrier
	parties not collaborating	critical barrier
	no agreed project design management process	critical barrier
	inflexible construction programme	critical barrier
	insufficient design resources	
	commercial decisions / lack of decisions affecting design	
	insufficient design management resources	
	designers lacking required skills	
	inflexible client programme	

Table 4.4: Selection, Pre-application and Application Barriers

A lack of leadership from senior management and no agreed DM processes were the critical pre-application barriers preventing the majority of users trying to implement new DM processes. The critical application barriers covered a greater number of barriers: lack of leadership from senior management, construction team and client ignoring design freeze / change control, parties not collaborating, no agreed DM processes and inflexible construction programme. Considered across pre-application and application critical barriers were a lack of leadership from senior management and lack of agreed DM processes. Furthermore, in a hierarchical analysis the lack of leadership from senior management and lack of agreed DM processes were the most influential barriers identified. These barriers originated within the sponsor and thus were under the sponsor's control. This demonstrated that the key barriers to implementing DM practices and tools can be influenced by the sponsor and therefore the sponsor has control over success of DM practices and thus the design process. To address the key implementation barriers it was decided to develop and test strategies to overcome the effect of these barriers on a project. This is discussed in 4.5.

Interviews also established that some tools were not required and also additional tools were necessary to help manage the design process. The majority of interviewees did not use tools P10 Job Description, D03 Decision Matrix and D04 Task Force Meeting claiming they did not help to manage the design process. It was decided to remove them from future versions of the DM Handbook. The interviews also established that some additional tools were necessary to manage the design process. As identified in Review Workshop 2, interviewees considered that commercial and procurement processes needed modification to be aligned with the new DM processes. Also a model designers' contract was identified as a way to limit delays in agreeing a contract acceptable to both parties.

4.5 CASE STUDY IMPLEMENTATION OF PRACTICES AND TOOLS

As noted in 4.4 some pre-application and application barriers were still affecting the implementation and success of DM practices and tools. Therefore, the preparation and implementation of the DM practices and tools was undertaken on one of the sponsor's projects. This was to understand the difficulties of implementing DM practices and develop further implementation strategies to address the barriers that were still affecting DM practices and tools and thus address objective 2.6. However, there was a five-month delay before an appropriate project became available. The impact of this limitation is discussed section 5.6.

The key barriers during the training initiative's pilot were lack of leadership from senior management and lack of agreed DM processes. It appeared that the second barrier could be addressed more directly and it was considered that the resolution of the former could be addressed by getting management to formally agree DM processes. The author was responsible for defining, agreeing (with all project parties) and implementing the project DM processes. This began by delivering DM Awareness v2 to the whole project team and Detailed DM Training v2 to design managers and design planners. This allowed all project team members to agree in principle to the DM Handbook practices and tools to be used and the associated awareness created a basis for addressing the key implementation barriers.

The starting point for defining project DM processes was a meeting held with the DM team (2 managers and 3 co-ordinators) to establish appropriate DM practices and tools. The majority of practices and tools were suitable, however, due to the nature of the project others were not, as shown in Table 4.5.

design management idea / tool		adopted on case study project		
		yes	no	comment
Rigorous team selection based on range of criteria			●	consultants already defined
Capture, clarify and own stakeholder requirements		●		
Understanding the process of design in detail		●		
Allow adequate design time		●		
Plan the design in detail and collaboratively		●		
Integrate design, procurement and construction activities		●		
Progressive freezing of design details		●		
Be more specific with design team scope of works		●		
Control issue of deliverables and information		●		
Manage interfaces		●		
Investigate and control potential design changes		●		
Focus development effort early in the process		●		
Involve parties at the right time in the process		●		
Monitor all design tasks and deliverables		●		
P01	brief document	●		
P02	concept design stage kick-off meeting		●	too late in process - not required
P03	tender design stage kick-off meeting	●		
P04	detailed design stage kick-off meeting		●	no clear tender and detailed design stages
P05	design change workshop	●		
P06	master design programme	●		
P07	consultant benchmarking		●	
P08	consultant interviews		●	
P09	discipline design programme	●		
P10	job description		●	too detailed and structured for project
C01	information transfer schedule	●		
C02	work package control document	●		built into P01
C03	co-ordination meeting	●		
C04	design workshop	●		
C05	staged information delivery	●		built into P06 process
C06	fix information	●		built into P06 process
C07	interface schedule	●		
D01	value analysis	●		
D02	brainstorming	●		
D03	decision matrix		●	would not be used by DM team
D04	task force meeting		●	would not be used by DM team
D05	design review document	●		built into P01
D06	design proposal document	●		built into P01
M01	progress report	●		
M02	progress meeting	●		

Table 4.5: DM Practices and Tools for Case Study Project

Rigorous Team Selection and associated tools P07 and P08 were not appropriate as consultants were already appointed. As the project had already passed the concept design stage there was no need for P02. Furthermore, the case study was a PFI project, therefore had no clear definition between tender and detailed design stages and as such P04 was considered unnecessary. The DM team decided they had no need for P10, D03 or D04, as they were not tools that they considered helped to manage the design process. All of the DM team's decisions supported the interview findings (4.4), strengthening the validity of the interview findings regarding tools that are and are not appropriate for DM. Further similarities to interview results became apparent when the DM team noted that streamlining of designers' briefing documentation was possible. They suggested P01 Brief Document, C02 Work Package Document, D05 Design Review Document and D06 Design Proposal Document could be combined in a single document to simplify the process.

Once the framework of DM practices and tools had been agreed it was necessary to formally prepare them for the project. It quickly became clear to the DM team that DM practices and tools needed minor modifications to be in line with contractual approval processes and other project processes (e.g. site specific health and safety and environmental considerations). Furthermore, while the Handbook generically identified key design process tasks it was insufficiently specific for the project. Therefore, a project guide was required to show how DM practices and tools support project DM processes, how DM processes interface with other project processes and allow access to DM tools. The author proposed a Project Design Management Plan (PDMP) that incorporated DM practices and other project operation's needs in DM processes while providing hyperlinks to modified DM tool templates and schedules. To ensure senior management demonstrated the required leadership, the PDMP process required formal approval by project heads of operation (e.g. DM, construction, procurement and commercial) and design disciplines. This was vital to align the PDMP with other project processes. Finally, the PDMP contained a guide for a six-monthly audit to check the implementation of PDMP processes.

Once prepared and formally agreed by all project heads of operation, the PDMP was implemented. In the three months of the case study all DM processes that could have been used were implemented successfully. The PDMP was also implemented on other projects retrospectively to address difficulties with DM processes and the sponsor decided to adopt it as a standard project document. Therefore, this exercise produced a key deliverable to help implement the DM training initiative in practice: a Project Design Management Plan and a set of DM tools modified to suit project requirements which has already been used on several projects.

The PDMP and its formal project agreement seemed to ensure DM practices and tools were implemented effectively on projects. Also, as it required that DM processes be defined and management to formally agree the processes it was considered an appropriate strategy to address two key implementation barriers: lack of leadership from senior management and lack of agreed DM processes.

4.6 DESIGN PROCESS PERFORMANCE INDICATORS

4.6.1 State of the Art Design Process Performance Indicators

Review Workshop 1 established that the sponsor should develop design performance indicators to report on the design process performance of projects and also help to reinforce changing DM practices with appropriate data. The research tasks and related findings are discussed in Paper 5. It is recommended that the whole paper be referred to at this stage.

The state of the art review of design process performance measurement, discussed in section 3.2, identified the characteristics to be monitored to ensure that design process performance is comprehensively reported: effectiveness, efficiency, productivity, quality and impact (Oakland and Sohal, 1996). It also established that while the construction industry has many current performance measurement projects, few focus on the design process. When they do, they often require users to undertake data collection to provide results which is unlikely to get them adopted (Kanter, 2000). Finally, it was established that no current practice addresses all of Oakland and Sohal's

(1996) process characteristics, therefore it was decided to develop DPPIs to monitor the sponsor's design process.

4.6.2 Development of Design Process Performance Indicators

To prepare suitable DPPIs for the sponsor and thus address objective 2.7 it was necessary to identify data representing design process performance, if and how the sponsor reports this data and then combine this knowledge with the performance indicator framework and Oakland and Sohal's design process characteristics. This was carried out by continuing the literature review, by investigating the sponsor's project systems to identify processes and tools used to manage the project and interviewing practitioners for their views on DPPIs. The methodology is explained in section 3.2.

A key barrier to construction industry implementation of performance indicators is that data for process monitoring is difficult to obtain (Cox and Morris, 1999). Without access to readily available data DPPIs would require practitioners to add data collection to their current tasks. However, a tool imposing unwanted disciplines on practitioners is unlikely to be adopted (Kanter, 2000). A previous performance measurement exercise by the sponsor to report construction performance experienced difficulties to involve employees as it expected them to undertake data collection in addition to their current tasks. For the DPPIs this was addressed by using data automatically collected as part of the design process as suggested by Globerson (1985). However, to avoid using data merely on the basis that it was readily quantifiable (Hinton *et al*, 2000) and ensure that it was appropriate for indicating design process performance, the data (and sources) relating to design process inputs and outputs was used. Table 4.6 summarises the results of this exercise.

The structured interviews with practitioners identified a range of project features they wanted monitoring, summarised as: deliverable production, iterations required to complete deliverable, deliverable completeness, control of RFIs (requests for information), resource use, cost of designed facility, approval delays, design change impacts. Words of warning were also offered: DPPIs should be simple, clear and understandable to all project parties – a point supported by Brunso and Siddiqi (2003).

process input	process output	data source
staff resources		planned and actual master and discipline programmes, project cost plan
	design deliverables	planned and actual master and discipline programmes, deliverable issue schedule
	project cost information	project cost plans
	requests for information (RFIs)	RFI report on document management system

Table 4.6: Key Design Process Inputs and Outputs

The literature review established that the design of performance measures is difficult with many potential pitfalls if indicators are poorly designed or the surrounding process is incomplete. A performance indicator design framework (Neely *et al*, 1997) was identified and modified by considering other comments (Fortuin, 1988; Crawford and Cox, 1990; Globerson, 1985; Maskell, 1991; Lantelme and Formoso, 2000; Bourne *et al*, 2000; Walsh, 2000; Cox and Thompson, 1998; Hopwood, 1984; Carpinetti and de Melo, 2002; Camp, 1995; Camp, 1989; Khurrum and Faizul Huq, 1999; Sink, 1985). It was used in combination with Oakland and Sohal's (1996) process characteristics, practitioners requirements and consideration of key process inputs and outputs to prepare a suite of DPPIs to comprehensively represent design process performance. Table 4.7 shows each DPPI and its associated purpose.

effectiveness	**efficiency**	**productivity**	**quality**	**impact**
% of planned deliverables issued	**average deliverable issue delay**	**% planned deliverable issued / % planned manhour costs**	**RFIs issued / deliverable issued**	**% project overrun due to design rework**
ensure required deliverables are being issued	*ensure deliverables issued in timely manner*	*identifies if resources used are producing corrrect level of resources*	*highlight if deliverables meet recipient's requirements*	*minimise delays due to design changes*
% of planned deliverables issued on time	**average RFI closing delay**		**average no. of revisions per deliverable**	**% project overspend due to design rework**
ensure required deliverables are being issued on time	*ensure RFIs responded to in timely manner*		*check design is being developed competently*	*minimise costs of design changes*
% of RFIs closed on time	**% of planned manhour costs**		**% content completion of issued deliverables**	
ensure RFI's closed when required	*ensure correct level of resources employed to meet commitments*		*highlight if deliverables meet recipient's requirements*	
% of planned deliverables approved for construction	**average comment issuing delay**			
ensure deliverables approved when required	*ensure documents not delayed unnecessarily by approver*			
	average delay in achieving approval			
	ensure deliverable comments issued in timely manner			

Table 4.7: Design Process Performance Indicators

To understand the conversion process from raw data to DPPI and identify barriers and how the data should be represented it was necessary to collect and convert sample data into the DPPIs. This is discussed in Paper 5 Section 5.

The data collection process encountered three barriers. Across all three projects electronic versions of RFI schedules were incomplete and deliverable comments were only recorded in paper format. However, this was addressed on two of the projects by using the project's extranets to manage RFIs and deliverable comments electronically. Unexpectedly illustrating the benefit of project extranet as a source of process performance data.

It was difficult to establish the programme impact of design changes as they were obscured by other programme modifications and agreed additional designer manhours due to the change were only available in paper format and did not identify impacts on other design, procurement and construction activities. The two ongoing projects addressed this barrier by using the new DM practices that require a complete analysis of a change before approval.

The data transformation process established that data was required from several disparate sources. By using modified and linked spreadsheets to collect, transform and present data into a single DPPI report this ensured that it was in a simple format as requested by practitioners and avoided any additional practitioner work as recommended by Kanter (2000). Also during data transformation, the lack of standard protocol for the format of deliverable schedules required that the spreadsheet calculations to convert data into DPPI values were modified for each project. Therefore, it was concluded that in the short term a standard deliverable schedule format should be used on projects where DPPIs are being used but also that future work should focus on more robust automatic data capture processes.

Globerson (1985) recommends performance indicators should be based on ratios rather than absolute values. However, the DPPIs reporting delays were expressed in weeks and the deliverable DPPIs shown in graphical format as planned and actual deliverable issue profiles instead of a percentage score of the actual to planned deliverables issued. This was to present them in a practitioner accessible format and illustrate the practical uses to improve adoption potential of the DPPIs.

When attempting to define DPPI targets it was difficult to define targets that were stretching (Globerson, 1985) without evoking frustration amongst those who have to achieve them (Walsh, 2000) and establish how project conditions might affect targets. It was resolved that future work should establish a set of appropriate DPPI targets that can account for varying project conditions.

This work prepared performance measurement techniques for practitioner testing by converting raw data into the DPPIs while addressing implementation barriers.

4.6.3 Practitioner Testing of Design Process Performance Indicators

The practitioner review of DPPIs was carried out through structured interviews with practitioners to address objective 2.8. This methodology is discussed in Section 3.2. It indicated that proposed DPPIs associated with the deliverable production process, use of staff resources and the impact of design changes are at least important if not essential to monitoring the design process. They particularly liked the graphical format of the deliverable-based DPPIs and the presentation of DPPIs in a single report was said to simplify use and reporting. However, 15 DPPIs were considered too many and measures associated with RFI control and revisions per deliverable were not important as it was suggested they do not relate to key issues. It was decided that the indicators associated with the deliverable production process, use of staff resources and the impact of design changes should form the basis of any practical deployment of DPPIs. These indicators still represented all Oakland and Sohal's (1996) process characteristics and thus a comprehensive illustration of design process performance. However, it was decided future work should pilot the indicators to determine their ability to monitor design process performance and to identify and address any implementation barriers to the DPPIs.

This work reviewed the usefulness of each DPPI in monitoring the design process performance and thus produced DPPIs for deployment to comprehensively monitor design process performance.

4.7 RESEARCH DEVELOPMENT MAP

Figures 4.6 to 4.10 provide a chronological overview of the research programme. They illustrate the activities, key findings, decisions and outputs during the course of the programme. Figure 4.5 is a key and explanation of how to read the maps. While several tasks may have addressed particular research objectives, for clarity each objective is linked to the final activity relating to its resolution.

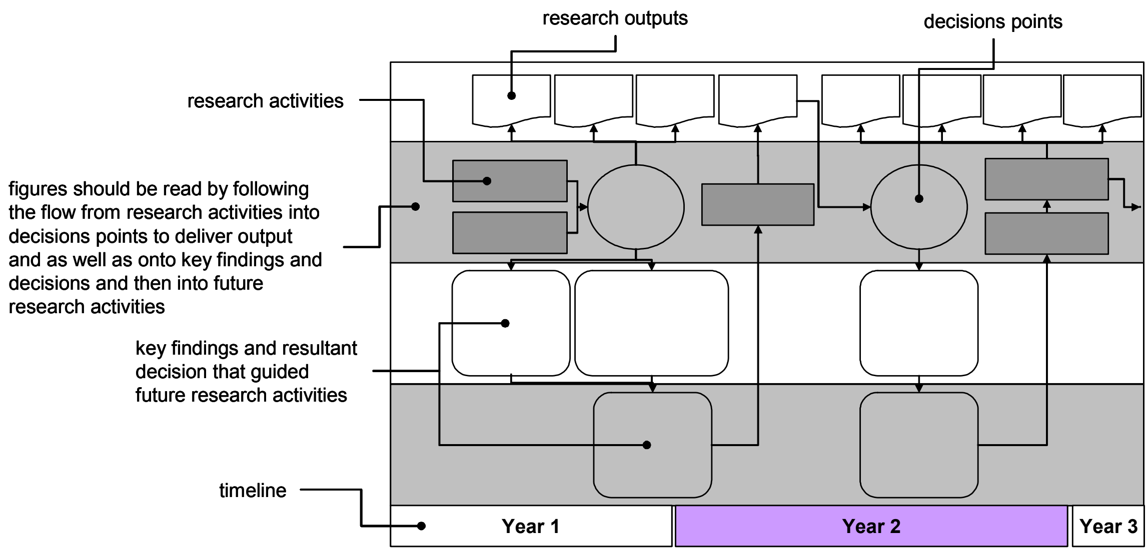

Figure 4.5: Key for Research Development Maps

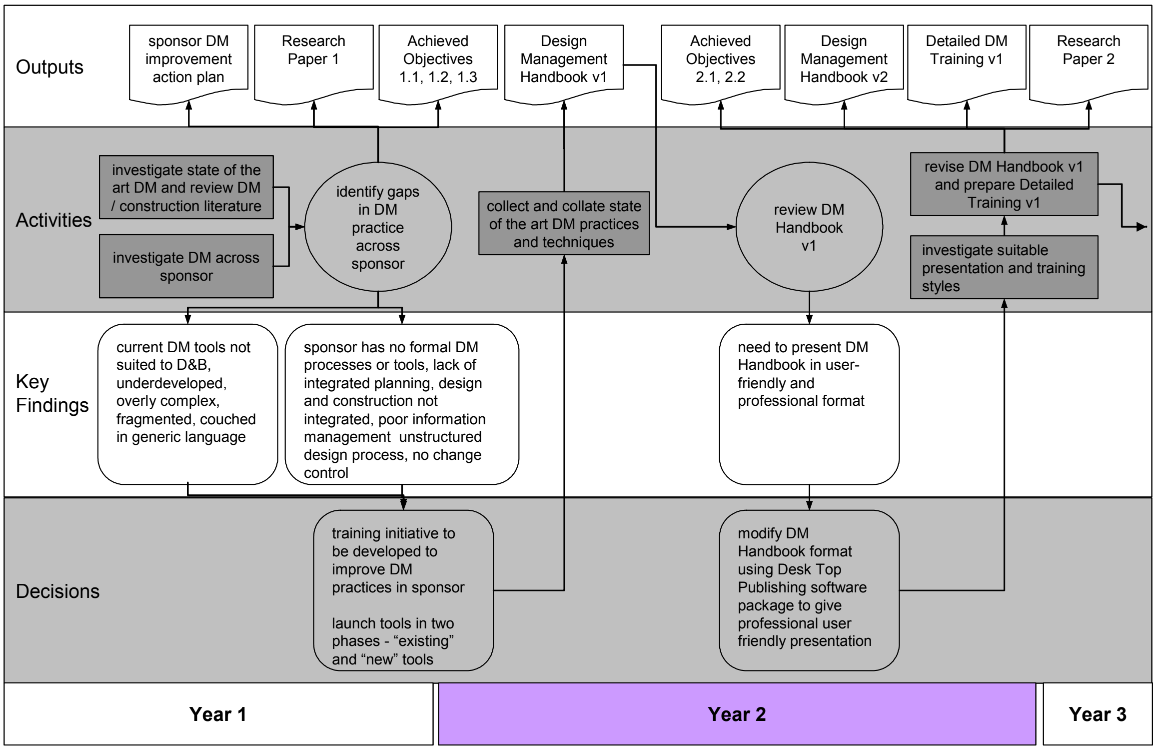

Figure 4.6: Research Development Map 1 of 5

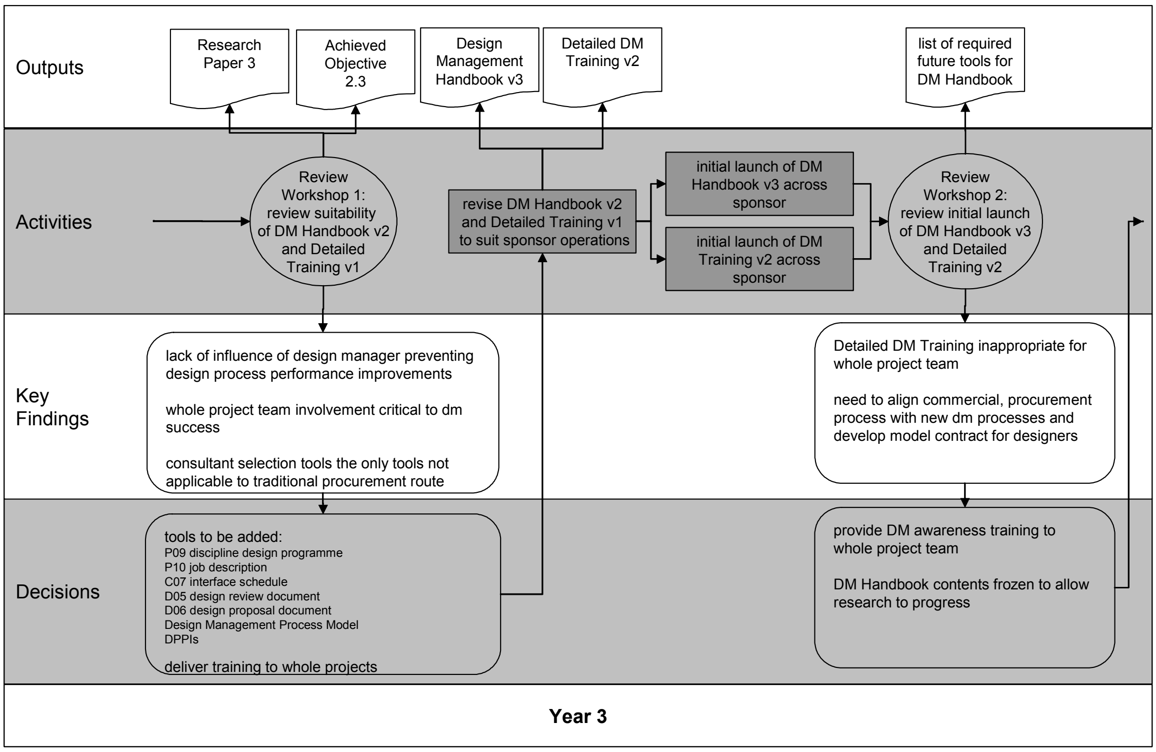

Figure 4.7: Research Development Map 2 of 5

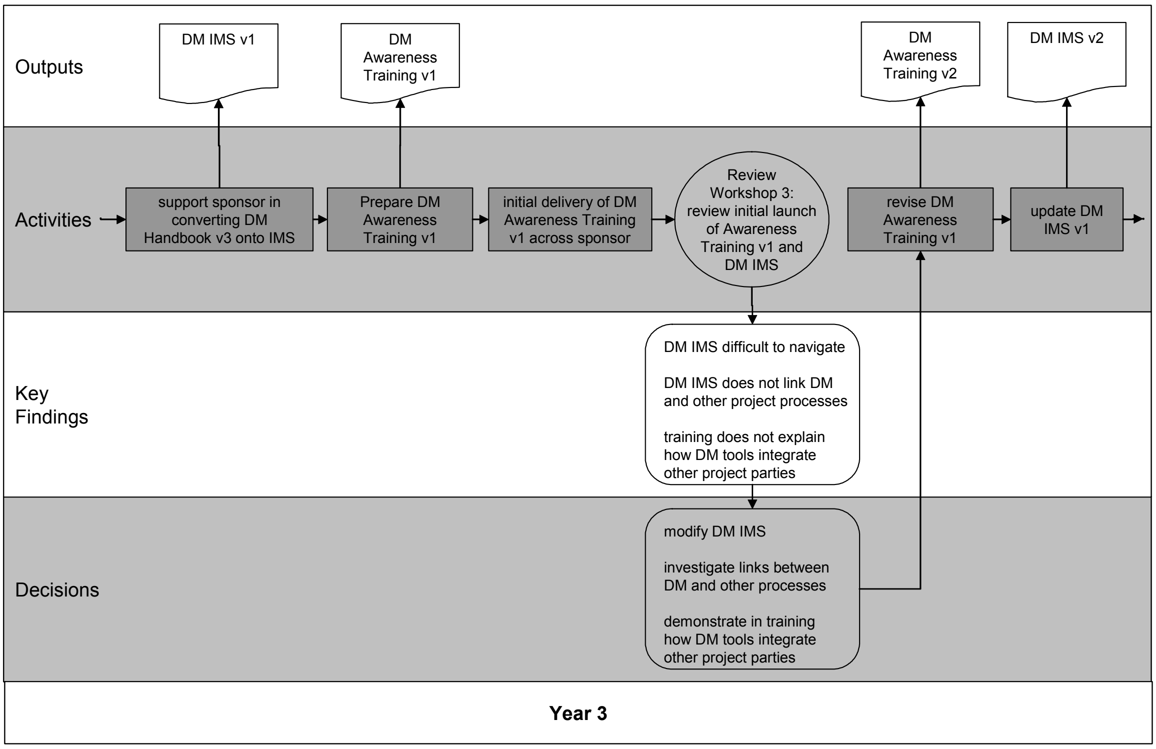

Figure 4.8: Research Development Map 3 of 5

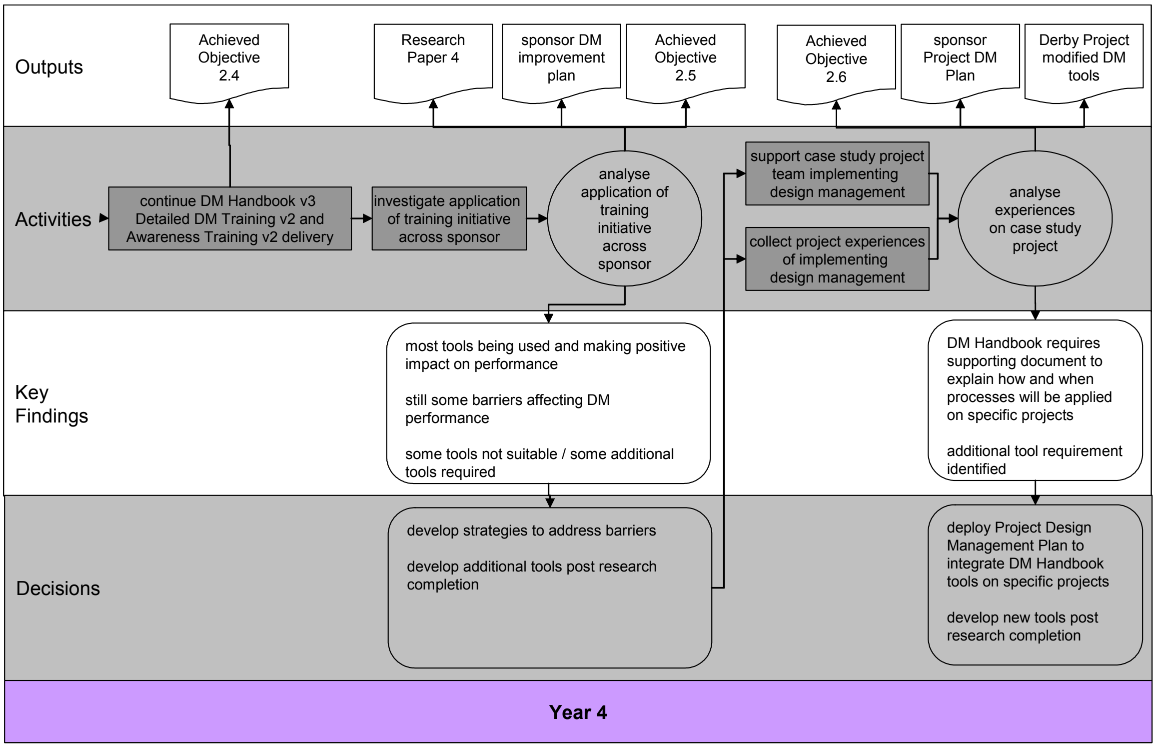

Figure 4.9: Research Development Map 4 of 5

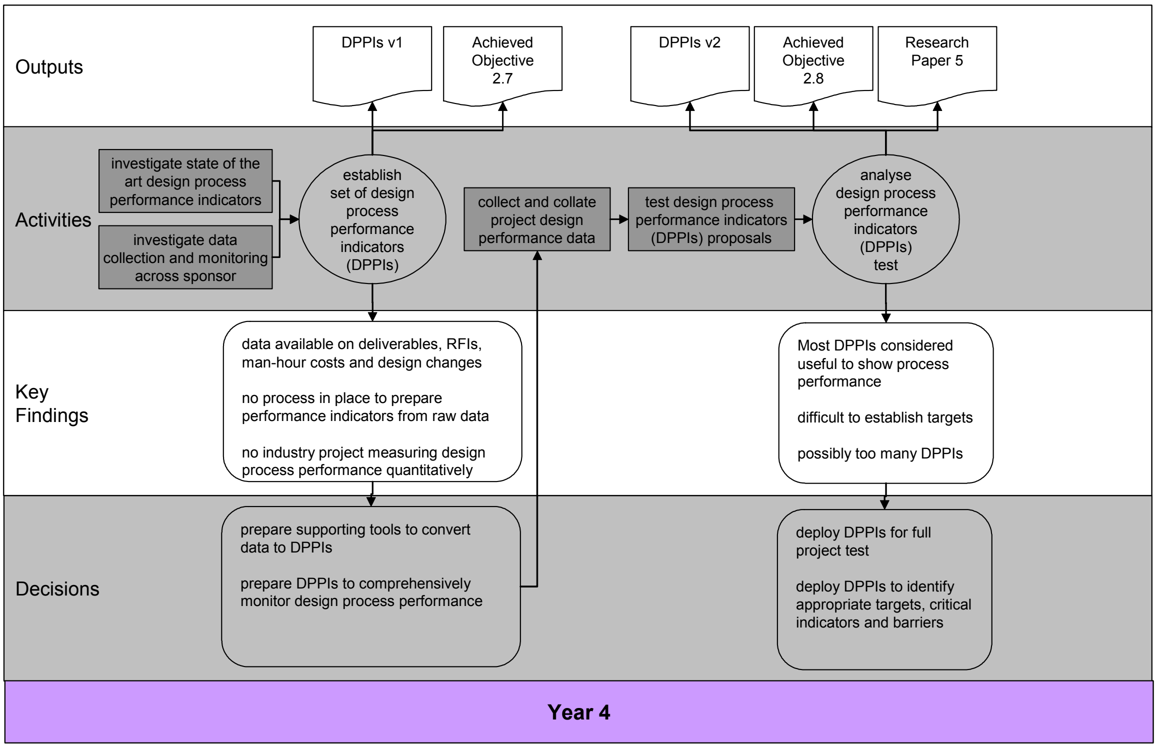

Figure 4.10: Research Development Map 5 of 5

5 CONCLUSIONS & IMPLICATIONS

5.1 CONCLUSIONS

The conclusions that can be drawn from the research in the course of addressing the aims and objectives of Phases 1 and 2 are described below.

5.1.1 Sponsors Current DM Practices

1. Many within the sponsor do not recognise the iterative nature of the process and to improve DM performance there is a need to improve understanding of the very nature of the design process and available tools should be used to manage the design process.

2. The sponsor undertakes DM in an inconsistent manner using approaches based on personal experience and preference rather than a structured approach. To be able to manage a process effectively it must be repeatable. The inconsistent way in which design is approached from project to project therefore makes effective DM difficult.

3. The sponsor uses few DM tools and they are applied inconsistently across projects.

4. The sponsor operates with an unstructured design process. This has led to the use of varying terminology to describe process stages and tasks. Companies implementing a structured design process should expect to experience the benefits of a common language to describe the process and an understanding of the tasks and responsibilities of each project party. From this it can be concluded that a structured design process can provide significant benefit by aligning the processes of project parties and providing an explicit road map to help manage each project.

5. Construction companies experience great difficulties in trying to manage the design process and it is apparent that the sponsor's employees are aware of the issues they must address to manage the design process. From this situation it can be concluded that people need more than an understanding of the barriers to managing the process in order to overcome them. To successfully manage the design process people must be equipped with knowledge and tools aimed at overcoming the barriers to managing the process.

6. The key areas for improving fundamentals of DM are: providing a structured and explicit design process; Design planning; Integrating design and construction; Information flow management and the ability to understand and predict the impact of design changes.

5.1.2 Training Initiative Development

7. The fundamental aim of the DM training initiative is to bring about a culture change by engendering a consensus amongst practitioners that existing methods are no longer delivering the desired results and then to convince them that other tools and techniques are appropriate to their requirements.

8. When implementing new practices it is it is necessary to devise strategies to address barriers to organisational change and the implementation of new tools in the construction industry. This significantly affected the training initiative's style, content and format. The writing style of tools and guidelines must use language and formats relevant to practitioners, as should any training workshops.

9. Many current DM tools, potentially appropriate to the sponsor's operations are fragmented, insufficiently developed, poorly deployed and couched in abstract terms, moreover, they tend to be overly complex and force practitioners into unwanted discipline. As such they are insufficiently developed for industry application and need considerable modification to ensure adoption in practice.

10. Implementing organisational change is a long-term process. Any change to DM practices must address many significant barriers. Therefore, it must be accessible to a range of professionals who have an influence on the design process. In conclusion, improving DM in practice is a long-term activity where the deployment effort must be sustained and varied to drive the required change and meet the training needs of the range of professionals involved in the process.

11. As successful DM relies on the actions of many project parties any changes to DM practices must educate all parties and as such training methods employed must be understood by and relate to all project parties. They must be educated about the importance of the design process in delivering value to the whole project, how the way they work affects the design process, how they can contribute to the design and consequentially the whole project process. Therefore, implementation of DM practices or tools must include and educate at all levels within an organisation and project team to ensure it is taken up in practice.

5.1.3 Testing Training Initiative

12. While DM is typically the role of one management function, it can be significantly affected by the actions of others, with design managers often unable to influence matters due to lack of authority.

13. The position of a design manager within the project team must be comparable to other senior managers to provide the authority necessary for the role.

14. The DM training initiative provides a sound understanding of the issues surrounding modern DM and practical ways of managing the process.

15. The initiative has the potential to change and improve DM performance within a design and construction organisation as it provides employees with a better understanding of the approaches, tools and practices that can help them improve the management of the design process.

5.1.4 Application of Training Initiative

16. The Handbook is being used and is useful for diffusing DM practices and tools and the training initiative has improved DM in practice.

17. The DM Maturity Model can help define and improve DM maturity.

18. Thirty out of thirty-nine practices and tools are critical to DM with practices and planning tools more resilient to barriers than co-ordination and development tools.

19. The critical impacts delivered most are a timely delivered design, a design meeting client requirements, a co-ordinated design and fewer late design changes, yet few practices and tools helped provide cost certainty of design.

20. Selection barriers can be very disruptive, yet do not occur often.

21. The lack of leadership from senior management and the absence of agreed DM processes are the critical pre-application barriers.

22. Lack of leadership from senior management, construction team and client ignoring design freeze / change control, parties not collaborating, no agreed DM processes and inflexible construction programme are the critical application barriers.

23. Lack of leadership from senior management and the lack of agreed DM processes are the critical barriers throughout the design process.

24. A Design and Build Contractor has the capacity to improve the success of DM practices within projects by reducing the effect of the barriers.

5.1.5 Case Study Implementation of Practices and Tools

25. Involving client and design team in the change process and using a Project Design Management Plan can help to implement DM practices and tools by overcoming key implementation barriers.

5.1.6 Design Process Performance Indicators

26. A Performance Indicator Framework helps to prepare a comprehensive performance indicator.

27. Many factors must be considered when designing performance indicators to avoid adversely influencing practitioners' behaviour or developing a system that no one will use.

28. No current design performance measurement initiative sufficiently covers all design process characteristics to be a comprehensive representation of design process performance.

29. It is possible to collect and convert relevant project data into design process performance indicators with no work outside practitioners' normal project tasks.

30. It is possible to develop a suite of performance indicators using standard project information, processes and software that represent a comprehensive picture of design process performance with no work outside practitioners' normal project tasks.

31. Practitioners consider DPPIs relating to deliverable production process, impact of design change and staff resource indicators important to monitor design process performance yet remain unconvinced by indicators relating to the control of RFIs.

32. There is a need to establish an appropriate set of DPPI targets dependent on project conditions.

33. There is a need to research the application of DPPIs in industry practice to test and refine suitable performance indicators for the construction design process.

5.2 REALISATION OF AIMS AND OBJECTIVES

Tables 5.1, 5.2 and 5.3 illustrate how the conclusions in 5.1 have realised the research objectives.

objective		conclusions	
1.1	to understand current DM practices in the sponsor	2	inconsistent approach to design management
		3	uses few and inconsistently applied range of tools across projects
		4	operates an unstructured process
1.2	to establish the presence and significance of knowledge gaps in DM processes and systems as applied in the sponsor	1	need to improve understanding of nature of design and use more tools to manage the process
		2	inconsistent approach to design management
		4	operates with an unstructured design process
1.3	develop a research programme into selected knowledge gaps in DM	5	to successfully manage design must equip with knowledge and tools aimed at overcoming the barriers to managing the process
		6	key improvement areas: structured and explicit design process, design planning, integrating design and construction, information flow management and the ability to understand / predict the impact of design changes

Table 5.1: Phase 1 Objectives and Conclusions

objective		conclusions	
2.1	to identify appropriate DM tools to employ within the sponsor	9	number of appropriate current tools, but need modification to use in practice
2.2	to prepare education training, implementation materials and documents for DM tools	7	training initiative to bring about a culture change by engendering consensus that existing methods are no longer delivering results and convince practitioners other techniques are appropriate
		8	when implementing new ways of working into industry must devise strategies to overcome barriers new ways are to be adopted. They have significant affect on style, content and format of the training initiative
		9	number of appropriate current tools, but need modification to use in practice
		10	organisational change is long-term where deployment must be sustained and varied to drive change and meet training needs of all professionals
		11	DM relies on the actions of many parties. Implementation of new DM practices must include and educate at all levels within an organisation and project team to ensure take up, therefore methods employed must be understood by and relate to all project parties
2.3	to review suitability of training and tools for application in the sponsor	14	DM initiative provides understanding of issues surrounding modern DM and practical ways of managing process
		15	initiative has potential to change and improve DM performance within D&C organisation. Employees given better understanding of tools and practices to help improve the management of the design process
2.4	to successfully disseminate and educate sponsor's staff in the application of DM tools	16	DM Handbook is being used and is useful for diffusing DM ideas and tools and the training initiative has improved design management in practice
2.5	to review the application of DM tools and identify resulting improvements in DM practice	16	DM Handbook is being used and is useful for diffusing DM ideas and tools and the training initiative has improved design management in practice
		18	30 out of the 39 ideas and tools are critical to design management with ideas and planning tools more resilient to barriers than co-ordination and development tools
		19	critical impacts delivered most: timely delivered design, design meeting client requirements, co-ordinated design and fewer late design changes, yet few ideas and tools helped provide cost certainty of design
2.6	to identify and overcome barriers to implementing DM tools	12	DM can be affected significantly by the actions of others, but design manager often unable to influence matters due to lack of authority
		15	initiative has potential to change and improve DM performance within D&C organisation. Employees given better understanding of tools and practices to help improve the management of the design process
		16	DM Handbook is being used and is useful for diffusing DM ideas and tools and the training initiative has improved design management in practice
		17	DM Maturity Model can help define and improve design management maturity
		20	Selection barriers can be very disruptive, yet do not occur often
		21	lack of leadership from senior management and no agreed design management processes are the critical pre-application barriers
		22	lack of leadership from senior management, construction team and client ignoring design freeze / change control, parties not collaborating, no agreed design management processes and inflexible construction are the critical application barriers
		23	lack of leadership from senior management and the lack of agreed design management processes are the critical design process barriers
		24	D&B contractors have capacity to improve DM by reducing effect of barriers
		25	involving client and design team in the change process and using a Project Design Management Plan can overcome implementation barriers and help implement DM ideas and tools in practice

Table 5.2: Phase 2 Objectives and Conclusions 1 of 2

objective		conclusions	
2.7	to identify and prepare appropriate performance measurement techniques to employ within the sponsor	26	Performance Indicator Framework helps prepare a comprehensive performance indicator
		27	must consider many factors when designing performance indicators to avoid adverse behaviour or developing a useless system
		28	no current design performance measurement initiative covers all design process characteristics
		29	possible to collect and convert relevant raw project data into DPPIs with practitioners' normal project tasks
		30	DPPIs can be developed using standard project information, processes and software to provide comprehensive view of process performance with practitioners' normal project tasks
2.8	to review suitability of performance measurement techniques for application in the sponsor	31	practitioners consider DPPIs relating to deliverable production process, impact of design change and staff resource indicators important to monitor design process performance yet remain unconvinced by indicators relating to the control of RFIs
		32	need to establish an appropriate set of DPPI targets dependent on project conditions
		33	need to research the application of DPPIs in industry practice to test and refine suitable performance indicators for the construction design process

Table 5.3: Phase 2 Objectives and Conclusions 2 of 2

Conclusions 2, 3 and 4 addressed objective 1.1 by illustrating that the sponsor had an inconsistent approach to DM, uses few and inconsistent range of tools and operates an unstructured process. The significance of the sponsor's current practices was identified by conclusions 1, 2, and 4, thus realising objective 1.2. The conclusions show the sponsor needed to improve understanding of the design process, use more DM tools, that its current approach makes DM difficult and a more structured process is required to improve DM. Conclusions 5 and 6 addressed objective 1.3, which finally realised aim 1 by demonstrating that the sponsor's employees needed equipping with the knowledge and tools to manage the design process and by defining the key areas to which such knowledge and tools should relate to improve the sponsor's DM.

Conclusion 9 realised objective 2.1 by showing that there were several tools that could be applied to improve the sponsor's DM performance. Objective 2.2 was achieved by conclusions 7, 9, 10, 11 by demonstrating the strategies to be used in the training initiative's design. Conclusions 14, 15 addressed objective 2.3 by showing that the initiative provides a sound understanding of modern DM as well as practices and tools to help improve management of the design process. By demonstrating that the DM Handbook is being used and that the initiative has improved DM practice, conclusion 16 showed that successful dissemination of DM practices and tools has taken place and thus realised objective 2.4. Objective 2.5 was achieved by conclusions 16, 18, 19 by identifying the improvements in DM practice delivered by the training initiative.
It is considered that objective 2.6 was not fully realised. However, considerable progress was made. Conclusions 12, 20, 21, 22, 23 show that several barriers were identified and conclusions 15, 16, 17, 25 illustrate that many of these barriers were addressed. However, the objective was to overcome the barriers and the associated aim asked for removal. It is now considered that such terminology was rather ambitious. It would be extremely difficult to confirm absolutely that the research had completely overcome all effects of implementation barriers. Therefore, while it cannot be confirmed that objective 2.6 was achieved it can be said that successful strategies have been developed for addressing the effect of implementation barriers.

Objective 2.7 was addressed by conclusions 26, 27, 28, 29 and 30. They showed how performance indicators should be designed to ensure they were practical and user friendly, that raw process data could be automatically converted into DPPIs after it was established that that current practice was not appropriate. Conclusions 31, 32 and 33 addressed objective 2.8 by illustrating the DPPIs that practitioners considered appropriate to monitor the design process and identifying where further work is required in relation to the development of DPPIs.

In respect of aim 2 many barriers have certainly been identified. However, due to the over-ambitious wording of objective 2.6 and aim 2, it could not be confirmed that the barriers had been removed from having any effect, therefore in the strictest sense aim 2 was not fully realised.

5.3 CONTRIBUTION TO KNOWLEDGE AND PRACTICE

This research has led to the development and implementation of a DM training initiative to improve the management of the construction design process. It has built on the work of others (Austin *et al*, 1999; Gray & Hughes, 2000; Lafford *et al*. 1998; Kagioglou, *et al*, 1998; Process Protocol 2; Cross, 1989; Lane and Woodman, 2000) by developing DM practices and tools by responding to issues and barriers identified in literature.

The research has identified the key processes that are the foundations of improving DM practice and demonstrated the ability of the initiative to improve DM and project performance. At a time when many in the industry are tackling DM performance and contractors are taking increasing responsibility for the design process this research has produced the first publicly funded initiative to deliver this improvement through DM training and the range of DM practices and tools to manage the design phase of projects.

By addressing implementation barriers, the development of the training initiative has produced a style and format that practitioners can understand, find user-friendly and contains a coherent and co-ordinated package of user-friendly practices and tools for practitioners. Furthermore, the work has demonstrated the practices and tools that are effective in managing the design process and the process impacts provided by practice and tools. At the same time it has established which practices and tools are most affected by implementation barriers and the key barriers preventing practices and tools from being deployed and effective in practice. Furthermore, it has developed strategies to overcome these barriers.

The research has shown the detrimental effect caused by the lack of power of DM within the project team structure and that this needs to be addressed if the process is to be successfully managed. Linked to this it has also demonstrated the potentially detrimental effect of other project disciplines on the performance of DM and the importance of including them and demonstrating their responsibility in the DM change programme. Out of this it identified that when the whole team is involved then significant improvements can be delivered.

As part of the development of the methodology, the research developed a quick, simple and easy to understand maturity test of an organisation's DM practices.

The research has demonstrated that not one current industry performance measurement initiative covers all design process characteristics and has developed a suite of DPPIs to represent these characteristics and address key implementation barriers.

5.4 IMPLICATIONS FOR THE SPONSOR / WIDER INDUSTRY

The research's primary impact for the sponsor is that it now has a DM training initiative comprising a DM Handbook containing practices and tools to manage the design process supported by Detailed and Awareness Training. As has been demonstrated on piloting projects, the sponsor will be able to train its design managers better, educate whole project teams about their role during the design process and ultimately manage the design process better to deliver projects on time that all stakeholder requirements. Furthermore, the initiative has demonstrably taken the organisation up a step in DM maturity and the piloting of the initiative has identified future issues to further improve DM practices.

The research has raised DM awareness across the sponsor and has been a part of a significant organisational change. Four years ago DM was a relatively small if difficult part of the business. It is now seen as crucial to project success. As such, the sponsor is now actively seeking a Board member to lead DM improvement across the business by October 2003.

The achievements within the sponsor have implications for the implementation of new DM practices and tools within, as well as outside the construction industry in new product development processes in manufacturing, automotive and aerospace industries.

Particular to the construction industry there is now a clear strategy for improving and implementing DM activities centred around the improvement mechanisms: structured and explicit design process, design planning; integrating design and construction, information flow management and understanding/predict design change impacts. In addition to this the critical tools and practices for successful design management are known as well as how to implement them in practice to overcome key implementation barriers. Furthermore, the DM Maturity Assessment can be used to provide a quick and easy means to assess a company's DM Maturity and set the agenda for a DM improvement strategy within other companies. Finally, this research provides guidance of the type and range of performance indicators that are appropriate to monitor the construction design process and how they can be designed to address potential implementation barriers.

There are lessons that can be extended beyond construction to other industries, and in particular to the manufacturing, automotive and aerospace industries. The Performance Indicator Framework (Paper 5) can be used to design any type of performance indicator and is not restricted to construction or even engineering. Furthermore, the knowledge of how to overcome implementation barriers associated with new practices and tools can be used to design suitable training material, new practices and tools to increase the potential for adoption in practice.

5.5 RECOMMENDATIONS FOR INDUSTRY / FURTHER RESEARCH

The research has made significant findings. However, it has also identified further questions, avenues for exploration and limitations of the exercise. There are several recommendations for further work, both academic, in addressing DM understanding, and industrial, dealing with the practical development of the training initiative, Handbook and DPPIs.

5.5.1 Academic Research

1. The training initiative has been principally developed within a large design and construction organisation. The experiences within SMEs should be explored to determine its relevance and impacts on other organisations.

2. Further testing of the DPPIs is necessary to identify and overcome any barriers to their deployment, establish appropriate targets as well as their ability to monitor design process performance.

3. Further investigation is recommended to develop DM tools to control costs of the designed facility.

4. The research identified that other project processes can have a significant impact on the design process. Research should focus exactly how and where other project processes should integrate with DM in order to deliver an effective and efficient project process.

5.5.2 Recommendations to Industry

1. A DM auditing process should be developed to ensure projects are deploying the DM practices and tools.

2. DM should have some representation at Board level to improve DM across a business, supported by the promotion of the Design Manager in the Project Management hierarchy or giving DM responsibility to Project Director.

3. Undertake project process performance monitoring to ensure that the design process is effective, efficient and productive.

4. The whole project team, design supply chain and client should be involved in DM Training and the definition of project DM processes, which should be presented in a Project Design Management Plan.

5. Commercial, procurement and construction processes should be aligned with the new DM practices and tools to deliver an effective and efficient project.

5.6 CRITICAL EVALUATION OF THE RESEARCH

As with any research activity, decisions were made during the investigation to focus on aspects of DM and close off other avenues to ensure useful conclusions were reached. However, such decisions inevitably limited the potential scope of investigation, leaving areas open for further research.

A primary limitation on the research was the sponsor's initial DM maturity. Phase 1 identified a need to improve DM practice generally. This affected the research both unfavourably and favourably. It ruled out in-depth investigations into specific areas such as design planning. Yet, it provided the opportunity to look at the holistic problem and define practices and tools for each step in the process.

Another key programme constraint was the requirement for commercial confidentiality. This restricted the training initiative's pilots to one organisation, which could have affected applicability of findings across the industry. However, this was understood at the outset and was mitigated by ensuring the training initiative was influenced by best practice within and outside the industry, as well as common barriers identified in literature. Therefore, research findings should be widely applicable to those in the industry involved in DM and the development of tools and practices to help the industry improve DM performance.

The dynamic industry environment also limited the research's scope. It was difficult to identify a project at the correct project stage for the case study exercise. The sponsor's projects were at bid stage (lack of potential to test practices and tools), considerably progressed into detailed design or construction (both far too progressed). Approximately five months passed before the sponsor won a project where the training initiative could be tested. The time remaining in the programme restricted the case study to developing strategies to overcome key implementation barriers with insufficient time to address other less critical barriers. There was also insufficient time to establish quantitative impact of practices and tools using DPPIs. However, considerable interviewee feedback from piloting the practices and tools provided a detailed illustration of the training initiative's performance.

Changes in the sponsor's Board of Directors resulted in the first improvement team being replaced by another. This stalled the initiative's development for around a month while the new team reviewed the initiative. While a useful exercise, again this restricted the time on subsequent activities.

While other project operations were supportive of the training initiative their processes were not modified to align them with the new DM processes and as a result were sometimes unable to react when design process improvements were delivered, resulting in the benefit being lost. This effect was reported by several interviewees and made it difficult to realise the true impact of the training initiative.

In summary, this research has made significant steps in understanding how to improve DM performance in practice and has developed practices, tools and training materials through which this can be achieved. It has established which are the critical DM practices and tools, the performance impacts that they can deliver, the barriers to their success and strategies to address key barriers. However, there is significant potential for further work to develop new tools and implementation strategies as well as testing the initiative in other companies.

6 REFERENCES

Alarcon, L.F. and Mardones, D.A., 1998, "Improving the design construction interface", "On the agenda of design management research", *Proceedings of the 6th International Group for Lean Construction Conference*, Guaruja, Brazil.

Alshawi, M. and Underwood, J., 1996, "Improving the constructability of design solutions through an integrated system", *Engineering Construction and Architectural Management*, Vol. 1, No. 2, pp 47- 67.

Akintoye, A., 1994, "Design and build: a survey of construction contractors' views", *Construction Management and Economics*, Vol. 12, No. 1, pp 155-163.

Anumba, C.J. and Evboumwan, N.F.O. 1996, "A concurrent engineering process model for computer-integrated design and construction", *Information Technology in Civil and Structural Engineering Design: Taking Stock and Future Directions*, pp 39-42.

Austin, S., Baldwin, A., Hammond, J., Murray, M., Root, D., Thomson, D. and Thorpe, A., 2001, *Design Chains: A handbook for integrated collaborative design*, Thomas Telford, London.

Austin, S., Baldwin, A., Hammond, J. and Waskett, P., 1999, "Application of the Analytical Design Planning Technique in the Project Process" in *Proceedings of the Conference on Concurrent Engineering in Construction*, VTT, Finland.

Austin, S.A., Baldwin, A.N., Li, B., Waskett, P., 1998, "Analytical design planning technique (ADePT): programming the building design process", Department of Civil and Building Engineering, Loughborough University, Leicestershire.

Austin, S.A., Baldwin, A.N., Newton, A.J., 1996. "A data flow model to plan and manage the build design process", *Journal of Engineering Design*, Vol. 7, No. 1, pp 3-17.

Austin, S.A., Baldwin, A.N., Newton, A. J., 1994, "Manipulating data flow models of the building design process to produce effective design programmes". *Proceedings of ARCOM Conference,* Loughborough, UK, pp 592-601.

Austin S, Baldwin A, Newton A.J., 1993, "Modelling Design Information in a Design and Build Environment", ARCOM Conference, pp 73-84.

Baldwin, A.N., Austin, S.A., Hassan, T.M., Thorpe, A., 1999, "Modelling information flow during the conceptual and schematic stages of building design", *Construction Management and Economics*, Vol. 17, No. 2, pp. 155-167.

Baldwin, A.N, Austin, S.A., Thorpe, A., Hassan, T., 1994, "Simulating the impact of design changes upon construction", P*roceedings of ARCOM Conference*, Loughborough, UK, pp 213-221.

Ballard, G., 2000, "Positive vs. negative iteration in design", *Proceedings of the 8th International Group for Lean Construction Conference*, Brighton, England.

Ballard, G. 1999, "Can pull techniques be used in design management?", CEC '99.

Ballard, G. and Howell, G., 1998, "Shielding production: An essential step in production control", *ASCE Journal of Construction Engineering and Management*, Vol. 124, No. 1, pp 18-24.

BEDC, 1987, "Achieving quality on building sites", Building and Economic Development Committee. NEDC.

Bogus, S., Songer, A.D., Diekmann, J., 2000, "Design-Led Lean", *Proceeding of Conference of the 8th International Conference for the Group for Lean Construction*, Brighton, England.

Bon, R., 1989, *Building as an economic process*, Prentice Hall, Englewood Cliffs, New Jersey, USA

Boothroyd and Dewhirst, 2003, www.design-iv.com

Bourne, M., Mills, J., Wilcox, M., Neely, A., Platts, K., 2000, "Designing, implementing and updating performance measurement systems", *International Journal of Operations and Production Management*, Vol. 20, No. 7, pp. 754-771.

BRE, 1995, "Project management: network analysis". Building Research Establishment.

Brenner, M., Brown, J., Canter, D., 1985, *The research interview: Uses and approaches,* Academic Press, London.

Brenner, M., 1981, Patterns of social structure in the research interview. In *Social method and social life*. (Ed M. Brenner) pp 115 – 158, Academic Press, London.

Brunso, T.P., and Siddiqi, K.M., 2003, "Using Benchmarks and Metrics to Evaluate Project Delivery of Environmental Restoration Programs", *Journal of Construction Engineering and Management*, Vol. 129, No 2.

Burati, J.L., Farrington, J.J. and Ledbetter, W.B., 1992, "Causes of quality deviations in design and construction", *Journal of Construction Engineering and Management,* Vol. 118, No. 1, pp 34-49.

Burnes, B. 1996, *Managing change: A strategic approach to organisational development*, Pitman, London.

Business Round Table, 2002, *Teamwork2000 – an experiment in collaborative working*, Business Round Table, Kenley, Surrey, UK.

Camp, R.C., 1995, *Business Process Benchmarking: Finding and Implementing Best Practices*, ASQC Quality Press, Wisconsin.

Camp, R.C., 1989, *Benchmarking: the Search for the Industry Best Practice that Leads to Superior Performance*, Quality Press, Madison, Wisconsin.
Carpinetti, L. C.R. and de Melo, A. M., 2002, "*What to benchmark? A systematic approach and cases*", Benchmarking: An International Journal, Vol. 9 No. 3, pp. 244-255.

CIDA, 1995 "Measuring up or muddling through: Best practice in the Australian non-residential construction industry, Construction Industry Development Agency and Master Builders, Australia, Sydney, Australia, pp 59-63.

Cockshaw, Sir A., 2001, Changing Construction Culture. In *Interdisciplinary design in practice*, (eds. R. Spence, S. Macmillan, and P. Kirby), Thomas Telford, London, pp 15-21.

Cole, E., 1993, *Planning building design work*, Architectural Management, Nicholson, M. (Ed), E& F. N. Spon, London.

Common, G., Johansen, E., Greenwood, D., 2000, "A Survey of the Take-Up of Lean Concepts Among UK Construction Companies", *Proceeding of Conference of the 8th International Conference for the Group for Lean Construction*, Brighton, England.

Cook, N., 2000, "Eurofighter Production Plant Wins 'Centre of Excellence' Rating", *Jane's Defence Weekly*, July 12, 2000.

Cornick, T., 1991, *Quality management for building design*, Butterworth, London, pp 218.

Cox, I. and Morris, J., 1999, "Process mapping: a quantitative study of post contract award design changes in construction", School of Industrial and Manufacturing Science, Cranfield University.

Cox, A. and Thompson, I., 1998, "On the appropriateness of benchmarking", *Journal of General Management*, Vol. 23 No. 3.

Crawford, K.M. and Cox, J.F., 1990, "Designing performance measurement systems for just-in-time operations", *International Journal of Production Research*, Vol. 28 No. 11, pp. 2025-2036.

Cross, N., 1989, *Engineering Design Methods: Strategies for Product Design*, John Wiley & Sons, New York.

Dean, E.B., 1996, "Concurrent Engineering from the perspective of competitive advantage", www.arc/masa/gpv

Edlin, N., 1991, "Management of engineering/design phase", *ASCE Journal of Construction Engineering and Management*, Vol. 117, No.1, pp 163-175.

Egan, C., 1995, *Creating Organisational Advantage*, Butterworth-Heinemann, Oxford.

Egan, Sir J., 2002, *Accelerating Change: a report by the strategic forum for construction,* Rethinking Construction c/o Construction Industry Council, London, UK.

Egan, Sir J., 1998, "Rethinking Construction: the report of the construction task force", *Department of the Environment, Transport and the Regions*, London, UK.

Eppinger, S., 1991, "Model based approaches to managing concurrent engineering", *Journal of Engineering Design*, Vol. 2, No. 4, pp 283-290.

Fellows, R. and Liu, A. 1997, *Research Methods for Construction*, Blackwell Science, Oxford.

Ferguson, K.J. and Teicholz, P.M., 1992, "Industrial facility quality perspectives in owner organisations", Technical Report 17, CIFE, Stanford University.

Filson, A. and Lewis, A. 2000, "Cultural issues in implementing changes to new product development process in a small to medium sized enterprise (SME)", *Journal of Engineering Design*, Vol. 11, No. 2, pp 149-157.

Firth, D., 1999, *Smart things to know about change*, Capstone Publishing, Oxford.

Ford Automobile Company, 1988, "FMEA manual, Design FMEA, Process FMEA", Brentwood, UK

Formoso, C.T., Tzotzopoulos, P., Jobim, M.S.S., Liedtke, R, 1998, "Developing a protocol for managing the design process in the building industry", *Proceedings of the 6th International Group for Lean Construction Conference*, Guaruja, Brazil.

Fortuin, L., 1988, "Performance indicators – why, where and how?", *European Journal of Operational Research*, Vol. 34 No. 1, pp.1-9.

Frankenberger, E. and Badke-Schaub, P., 1998 "Modelling design processes in industry- empirical investigations of design work in practice", *Automation in Construction*, Vol. 7, No. 2-3, pp 139-155.

Franks, J., 1992, "Design and build tender – do we need a code of practice?", *Chartered Builder*, June, pp 8-10.

Freire, J. and Alarcon, L.F., 2000, "Achieving a lean design process", *Proceeding of Conference of the 8th International Conference for the Group for Lean Construction*, Brighton, England.

Frost, R.B.: "Why does industry ignore design science". *Journal of Engineering Design*, Vol. 10, No. 4, 1999, pp 301-304.

Galpin, T. 1996, "Connecting culture to organisational change", *HR Magazine*, March.

Galhenage, G.P., 1994, "Comparison of traditional engineering and CE approach", *Department of Computer Engineering,* Salford University, UK.

Globerson, S., 1985, "Issues in developing a performance criteria system for an organisation", *International Journal of Production Research*, Vol. 23 No. 4, pp. 639-646.

Gray, C., and Hughes, W., 2001, *Building Design Management,* Butterworth Heinemann, Oxford.

Gray, C., Hughes, W. and Bennett, 1994, *The Successful Management of Design*, Centre for Strategic Studies in Construction, The University of Reading.

Hammond, J., Choo, H. J., Austin, S., Tommelein, I.D., Ballard, G. 2000, "Integrating design planning, scheduling, and control with Deplan" in *Proceedings of the 8th International Group for Lean Construction Conference*, Brighton, England.

Hedges I.W, Hanby V.I, Murray M.A.P, 1993, "A Radical Approach to Design Management", *Proceedings of CLIMA 2000 Conference*, London, pp 295-314.

Heath, T., Scott, D., Boyland, M., 1994 "A prototype computer based design management tool", *Construction Management and Economics*, Vol. 12, No. 6, pp 543-549.

Heppenstall, R., and Lewis, A., 1996, "Some Key Issues in Implementing Concurrent Engineering with SMEs", CEEDA '96, Conference, Poole, UK.

Hinks, J., Aouad, G., Cooper, R., Sheath, D., Kagioglou, M., Sexton, M., 1997, "IT and the design and construction process: a conceptual model of co-maturation", *International Journal of Construction Information Technology*, Vol. 5, No. 1, pp 1-25.

Hinton, M., Francis, G. and Holloway, J., 2000, "Best practice benchmarking in the UK", *Benchmarking: An International Journal*, Vol. 7 No. 1, pp. 52-61.

Hopwood, A.G., 1984, *Accounting and Human Behaviour*, Prentice-Hall, Englewood Cliffs, New Jersey, USA.

Howell, G.A., and Koskela, L., 2000, "Reforming Project Management: The Role of Lean Construction", *Proceeding of Conference of the 8th International Conference for the Group for Lean Construction*, Brighton, England

Huovila, P., Koskela, L., Lautanala, M., 1997, Fast or Concurrent: the art of getting construction improved, in *Lean Construction*, Alarcon, L.F.(Ed), A.A. Balkema, Rotterdam, The Netherlands, pp 143-159.

Josephson, P-E. and Hammerlund, Y., 1996, "Costs of quality defects in the 90's", Report 49, Building Economics and Construction Management, Chalmers University of Technology, pp 125.

Kagioglou, M. Cooper, R., Aouad, G., Hinks, J., Sexton, M., Sheath, D., 1998, "Generic design and construction process protocol final report", *The University of Salford*, Salford, UK.

Kalay, Y.E., Khemlani, L., Choi, J.W., 1998 "An integrated model to support distributed collaborative design of buildings", *Automation in Construction*, Vol. 7, No. 2-3, pp 177-188.

Kanter, J., 2000, "Have we forgotten the fundamental IT enabler: ease of use", *Information Systems Management*, Vol., 17, Pt. 3, pp 71- 77.

Karhu, V. and Lahdenpera, P., 1999, "A formalised process model of current Finnish design and construction practice", *The International Journal of Construction Information Technology*, Vol. 7, No. 1, pp 51-71.

Kettley, P. 1995, "Is flatter better? Delayering the management hierarchy", *The Institute of Employment Studies, Report 290*.

Khurrum S. Bhutta and Faizul Huq, 1999, "Benchmarking - best practices: an integrated approach", *Benchmarking: An International Journal*, Vol. 6 No. 3, pp. 254-268.

Koskela, L., 1999, "Management of production in construction: a theoretical view", *Proceedings of the 7th International Group for Lean Construction Conference,* University of Berkeley, California, USA.

Koskela, L., Ballard, G., Tanhuanpaa, V-P. 1997, "Towards lean design management" in *Proceedings of the 5th International Group for Lean Construction Conference*, Gold Coast, Australia.

Koskela, L. and Huovila, P., 1997b, "On the foundations of concurrent engineering", *1st International Conference on Computing in Structural Engineering*, Anumba, C.J. & Evbuomwan, N.F.O. (Ed), 3 - 4 July, Institution of Structural Engineers. London.

Koskela, L., 1992, "Application of the New Production Philosophy to Construction", Technical Report No. 72, CIFE, Standford University.

Kochan, A., 1991, "Boothroyd / Dewhirst – quantify your designs", *Assembly Automation*, Vol.11, No. 3, pp 12-14.

Kvan, T., 2000, "Collaborative design: what is it?", *Automation in Construction*, Vol. 9, No. 4, pp 409-415.

Lafford, G., Penny, C., O'Hana, S., Scott, N., Tulett, M., Buttfield, A., 1998, *Managing the Design Process in Civil Engineering Design and Build - a guide for Clients, Designers and Contractors, Funders Report CP/59*, Construction Industry Research and Information Association, London.

Lantelme, E. and Formoso, C.T., 2000, "Improving performance through measurement: the application of lean production and organisational learning principles", *Proceedings of the 8th International Group for Lean Construction Conference*, Brighton, England.

Latham, Sir M.: "Constructing the Team", *HMSO*, London, 1994.

Lane, R. and Woodman, G., 2000, "Wicked Problems, Righteous Solutions – Back to the Future on Large Complex Projects", *Proceedings of the 8th International Group for Lean Construction Conference*, Brighton, England.

Lawson, B., 1997, *How designers think*, 3rd Edition, The Architectural Press Ltd, London.

Lean Aerospace Initiative, 2003, www.mit.edu/lean/

Lewis, P., Norris, G., Warwick, G., 2000, Manufacturing Technology: Building to Win, *Flight International*, July 25-31, 2000.

Love, P.E.D., Mandal, P., Smith, J., Li, H. 2000, "Modelling the dynamics of design error induced rework in construction", *Construction Management and Economics*, Vol. 18, Pt. 5, pp 567-574.

McLellan, A., 1994, "Future positive", *New Builder*, 10 June, pp 26-28.

McManus, H. L., Millard, R., 2002, "Value Stream Analysis and Mapping for Product Development", *Proceedings of the 23rd International Council of the Aeronautical Sciences Congress*, Toronto, Canada.

Machowski F. and Dale, 1995, "The application of quality costing to engineering changes", *International Journal of Materials and Product Technology*, Vol. 10, No. 3, pp 378-388.

Marosszeky, M. and Karim, K., 1997, "Benchmarking – a tool for lean construction", *Proceedings of the 5th International Group for Lean Construction Conference,* Gold Coast, Australia.

Marshall, J., 1992, "Construction industry – its ailments and cures", *Chartered Builder*, June, pp 11.

Maskell, B.H., 1991, *Performance Measurement for World Class Manufacturing*, Productivity Press, Portland.

Melhado, S. B., 1998, "Designing for Lean Construction", *Proceedings of the 6th International Group for Lean Construction Conference*, Guaruja, Brazil.

Miles, R. S., 1998, "Alliance Lean Design / Construct on a Small High Tech. Project", *Proceedings of the 6th International Group for Lean Construction Conference*, Guaruja, Brazil.

Mitropoulos, P. and Tatum, C.B., 2000, "Management-driven integration", *Journal of Management in Engineering*, Vol. 16, Pt. 1, pp 48-58.

Mohamed, S. 1999, "What do we mean by construction process re-engineering?", *International Journal of Computer Integrated Design and Construction*, Vol. 1, No. 2, pp 3-9.

Mohsini, R., 1984, "Building procurement process: A study of temporary multi-orgainsations", *PhD thesis*, Universite de Montreal, Faculte l'Amenagement. Montreal, Canada.

Mohsini, R. and Davidson, C: "Determinants of performance in the traditional building process", *Construction Management and Economics*, Vol. 10, No. 4, 1992, pp 343-359.

Mokhtar, A., Bedard, C., Fazio, P., 2000 "Collaborative planning and scheduling of interrelated design changes", *Journal of Architectural Engineering*, Vol. 6, No. 2, pp 66-75.

Moore, D.R. and Dainty, A.R.J., 1999, "Work-group communication patterns in design and build project teams: an investigative framework", *Journal of Construction Procurement*, Vol. 6, No.1, pp 44-53.

Morris, J., Rogerson, J., Jared, G., 1999, "A tool for modelling the briefing and design decision making processes in construction", *School of Industrial and Manufacturing Science*, Cranfield University, Cranfield, UK.

Moser, C.A. and Kalton, G., 1971, *Survey Methods in Social Investigation*, 2nd Ed., Dartmouth.

Nadler, D., 1993, Concepts for the Management of Organisational Change, *from Managing Change* (2nd Ed), Mabey C., and Mayon-White, B., (eds), Paul Chapman Publishing, London.

NCE, 2002, www.nceplus.co.uk

Neely, A., Richards, H., Mills, J., Platts K. and Bourne, M., 1997, "Designing performance measures: a structured approach", *International Journal of Operations & Production Management*, Vol. 17 No. 11.

Newton, A.J., 1995 "The improved planning and management of multi-disciplinary building design", *PhD thesis*, Department of Civil and Building Engineering, Loughborough University, Leicestershire.

Newton, A. and Hedges, I., 1996, "The improved planning and management of multi-disciplinary building design", *CIBSE / ASHRAE Joint National Conference*.

Oakland, J. and Sohal, A., 1996, *Total Quality Management: Text with Cases*, Butterworth Heinemann, Melbourne, Australia.

O'Brien, M.J., 1997, "Integration at the limit: construction systems", *International Journal of Construction Information Technology*, Vol. 5 No. 1, pp 89-98.

Office of Government Commerce, 2002, www.ogc.gov.uk

Ogunlana, S., Lim, J., Saeed, K. 1998, "DESMAN: a dynamic model for managing civil engineering projects", *Computers and Structures*, Vol. 67, No. 5, pp 401 - 419.

Powell, J. A.; Newland, P., 1994, "Informing multimedia: a sensitive interface to data for construction design professionals" *Design Studies*, Vol. 15, No. 3, pp 285.

Prescott, Rt. Hon. J., 1999, Department of Transport and the Regions press release, 19 July 1999.

Pressman, A., 1993, *Architecture 101: a guide to the design studio*, Wiley, New York

Process Protocol 2, http://pp2.dct.salford.ac.uk/homepage.htm

Pugh, D., 1993, Understanding and managing organisational change, *from Managing Change* (2nd Ed), Mabey C., and Mayon-White, B., (eds), Paul Chapman Publishing, London.

Race, P. 2001, *2000 Tips for Lecturers*, Kogan Page, London.

Rapp, R., 2001, "Evolution not revolution", *Journal of Management in Engineering*, Vol. 17, No. 3, pp 166 - 175.

Reinertsen, D.G., 1997, *Managing the Design Factory*, The Free Press, New York, pp 269.

Richardson, G., 1991, *Feedback thought in social science and systems theory*, University of Pennsylvania Press, Philidelphia.

Rosenthal, S.R. and Tatikonda, 1992, *Integrating Design and Manufacturing for Competitive Advantage*, Competitive Advantage Through Design Tools and Practices, Oxford University Press, Oxford, UK.

Saxon, R., 1998, "Response from the industry", Speech made to the 1998 Conference of the Design and Build Foundation, BAFTA, London, 21st October 1998.

Sheath, D.M., Woolley, H., Cooper, R., Hinks, J. and Aouad, G., 1996, "A process for change – the development of a generic design and construction process protocol for the UK construction industry", *Proceedings of InCIT '96*, Syndey, Australia.

Sink, D.S., 1985, *Productivity Management: Planning, Measurement and Evaluation, Control and Improvement*, John Wiley, New York.

Songer, A.D., Diekmann, J., Hendrickson, W., Flushing, D., 2000, "Situational Re-engineering: Case Study Analysis", *Journal of Construction Engineering and Management*, Vol. 126, No. 3, pp 185-190.

Spence, R., 2001, Interdisciplinary Design in Practice. In *Interdisciplinary design in practice*, (eds. R. Spence, S. Macmillan, and P. Kirby), Thomas Telford, London, pp 15-21.

Squeo, A. M., 2000, "Lockheed Plant in Georgia Sees a Turnaround", *Wall Street Journal*, July 9, 2000.

Steele, J., Parker, A., Kirby, P., 2001, Working Together: Short Courses for Design Teams. In *Interdisciplinary design in practice*, (eds. R. Spence, S. Macmillan, and P. Kirby), Thomas Telford, London, pp 140-151).

Steele, J., 1999, *"A methodology for engineering design research",* Department of Civil Engineering, Loughborough University.

Sterman, J.D., 1992, "*Systems dynamics modelling for project management*", working paper, Systems Dynamics Group, Sloan School of Management, MIT, Cambridge, MA.

Strassman, H.B., 1995, "A Bias for Action", *ENR*, McGraw-Hill Companies Inc, pp 28-32.

Taylor A.J., 1993, "The Parallel Nature of Design", *Journal of Engineering Design,* Vol.4, No.2, pp 141-152.

Tluazca, G.J. and Daniels, S.H., 1995, "A Market Measured in Microns and Megaprojects*", ENR*, McGraw-Hill Companies Inc, pp 34-38.

Treasury Task Force, 2000, *How to Achieve Design Quality in PFI Projects*, Technical Note 7, HM Treasury.

Thomson, D.S. and Austin, S.A., 2001, "Construction Value Management Revisited: The designer's role" in *Proceedings of Cobra 2001 Conference*, Glasgow Caledonian University, Glasgow, UK, RICS Foundation.

Ulrich, K.T. and Eppinger, S.D., 1999, *Product design and development*, 2nd Edition, McGraw Hill, New York.

UK Lean Aerospace Initiative, 2003, Society of British Aerospace Companies (SBAC), www.sbac.co.uk

Urban Task Force, 1999, *Towards an Urban Renaissance*, E. & F. N. Spon, London.

Walsh. P., 2000, "How to assess performance targets and how to assess performance against them", *Benchmarking: An International Journal*, Vol. 7 No. 3, pp. 183-199.

Williamson, B., Bright, D., and Parkin, B., 2001, "Management Learning and Team Based Working", *Management Research News*, Vol. 24 No. 1/2, pp 56-67.

White, K. 1979, "The Scanlon Plan: causes and correlates of success", *Academy of Management Journal*, Vol. 22, June, pp 292-312.

Womack, J.P., Jones, D.T., Roos, D., 1990, *The Machine that Changed the World*, Harper Perennial.

Womack, J. P. and Jones, D. T., 1996, *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*, Simon & Schuster, Sydney.

Yin, R.K., 1984, *Case study research: Design and Methods*, 2nd Edition, Sage Publications, Thousand Oaks.

APPENDIX A PAPER 1

Bibby, L., Austin, S., Bouchlaghem, N., 2003, "Defining an improvement plan to address design management practices: a case study of a UK construction company" *International Journal of IT in Architecture, Engineering and Construction* (*IT-AEC),* Vol. 1, Issue 1.

DEFINING AN IMPROVEMENT PLAN TO ADDRESS DESIGN MANAGEMENT PRACTICES: A CASE STUDY OF A UK CONSTRUCTION COMPANY

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ABSTRACT
Barriers to managing the construction design process are preventing the UK construction industry from delivering projects on time, to budget and to the specified quality. This paper focuses on these barriers and how they affect design management performance. The paper is based on a case study, conducted with a major UK civil and building design and construction company that is improving its design management performance. The paper highlights the impact of the nature of the process and current management practices on the ability to manage the design process. It discusses the current views and approaches to design management within the case study company, puts forward a strategy capable of driving change in design management practice and explains how this is being deployed within the company. This paper is likely to be of interest to those involved in design management and the development of tools and practices to improve design management performance in industry.

Keywords: construction, design, management, industry practice, process, tools.

1. INTRODUCTION
In the construction industry, design is a key activity where the customer's needs and requirements are conceptualised into a physical model of procedures, drawings and technical specifications, in the process defining up to 70% of the cost of the final product [1]. The design phase also has many interfaces with other processes, such as construction and procurement, and organisations including the client, user representatives and regulatory bodies.

Historically, design was manageable with simple planning and management techniques. However, management of the design process has become increasingly complex as a result of factors such as fast tracking and the increasing complexity of the fabric and content of buildings, requiring enormous co-ordination effort, which rarely achieves it goals [2]. It is characterised by poor communication, lack of adequate documentation, deficient or missing input information, poor information management, unbalanced resource allocation, lack of co-ordination between disciplines and erratic decision making [3, 4, 5, 6, 7].

The cause of the majority of construction delays and defects can be related to poor design performance [8, 9] frequently creating problems that are more significant than those attributed to poor workmanship and site management [10]. This scenario is very familiar to the company under investigation and has been a major driver to improving design management performance.

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This paper investigates the impact of the nature of the process and current management practices on the ability of construction companies to manage the design process. It discusses the methodology, results and conclusions of an initial study undertaken within the case study company. The case study uncovers the current views and approaches to design management within the company, and identify areas where improvement is necessary. Many of these are likely to be relevant to other design organisations, particularly those that have evolved into design and building from traditional contracting. We then describe a strategy for driving change within such design and construction organisations.

2. BARRIERS TO MANAGING THE DESIGN PROCESS

Though there is growing interest in design management within the UK construction industry, there are several barriers that must be addressed if it is to succeed. These barriers are related to the nature of the design process and current management practices:

Nature of the design process

A. ***Iterative nature of the design process -*** the effects of complexity and uncertainty in the design process requires significant management effort [6, 11, 12].
B. ***High volume of information to be collected, co-ordinated and analysed -*** the availability of, and access to, information is the most important factor affecting performance of the building design process [13, 14], yet this often breaks down as a result of "collective amnesia" [15].
C. **Many parties with differing needs -** the fragmented nature of the UK construction industry inhibits performance improvement [16], leaving each project party to have different goals from each other with client value not considered to a significant degree [17].
D. ***Changes can significantly affect progress*** - design changes are a primary factor that contributes to time and cost overruns during projects [18].

Current management practices

E. ***Unstructured design process -*** the design process is poorly defined and mere verbal communication cannot create sufficient understanding of a process between various parties [19]. If people are to work together effectively an ordered approach to the design process is essential [20].
F. ***Design not planned in enough detail -*** traditionally, it was believed that design could not be planned in detail [21]. A lack of detailed design planning results in insufficient information being available to complete design tasks and causes conflicts on construction documents [2].
G. ***Parties work to different processes -*** the separation of design from the rest of the project process is a fundamental weakness in the construction industry [16]. Yet, integration during the design phase is critical to prevent problems in subsequent phases and select suitable design solutions [17].
H. ***Poor information co-ordination -*** the principal design activity of any project is the processing of information [22, 15]. However, co-ordination is one area in which construction is perceived to perform poorly [23, 24].

3. CASE STUDY

The company studied is one of the top five civil and building design and construction companies in the UK with interests in PFI, design and build as well as traditional contracting. The company recognises it has to make a step change in how it is managing the design process in order to gain competitive advantage over its rivals. To deliver these changes a partnership of the company, Loughborough University and the Engineering and Physical Sciences Research Council (EPSRC) is supporting a research project on design management, as part of a four year Engineering Doctorate (EngD) Programme delivering changes to design management understanding and practices.

4. METHODOLOGY

The methodology adopted to meet the research objectives was based on a previous approach [25] and comprised a literature review, review of current and recent research projects in the field, semi-structured interviews with company staff and triangulation of interview results with literature.

The review of design management literature provided an up-to-date understanding of design management in the industry as well as helping to formulate a framework for conducting the semi-structured interviews. The triangulation stage of the investigation was used to validate interview results and identify tools and practices to address problems facing the company. The review of current and recent research projects in the field indicated where the research could focus to provide competitive advantage to the company while ensuring it did not duplicate any existing work.

Semi-structured interviews were used to collect data from fifteen individuals (directors, project managers, construction managers, design managers and design engineers) relating to current design management practices and problems within the company. They were preferred to structured interviews, where respondents are offered only a limited range of answers which has the risk of leading to biased views. At the other extreme unstructured interviews can produce data that are both difficult and laborious to code and analyse. Good practice in conducting interviews was used in this research [26]. The interview results were categorised and triangulated with literature as a validation exercise. Triangulation also helped to highlight underlying causes of problems identified by interviewees and potential solutions to the problems.

The interviewees identified a significant number of improvement areas to address in current design management practice. Each improvement area was ranked based on the frequency with which it was raised by the interviewees. This identified the most critical issues that needed to be addressed within the company. To discover whether there were any common themes underlying these issues, the root cause for each issue was identified from literature as were potential ways of addressing each root cause (improvement mechanisms). This exercise allowed the research team to identify the improvement mechanisms that were necessary to address each issue raised by the interviewees. The improvement mechanisms are:

- Structured and explicit design process;
- Improved design planning;
- Integration of design and construction;
- Information flow management;
- Understand/predict impact of design changes; and

- Feedback systems.

To understand which improvement mechanisms would offer the greatest benefit to the company (i.e. those strategies that allow the company to address the most critical and greatest range of issues) they were ranked based on an "importance weighting" calculated using Equation 1.

$$X_i = \frac{(A_i Y_i)}{\Sigma(A_i Y_i)}$$

A_i - sum for all issues the number of interviewees identifying each issue which can be solved (or part solved) by improvement mechanism "i"

Y_i - number of issues to which improvement mechanism "i" is applicable

Equation 1: Importance weighting, X_i for each improvement mechanism

The weighting exercise provided a simple ranking system for the improvement mechanisms. It indicated the potential each improvement mechanism has to address the range of issues identified by interviewees. This is a measure of the importance of each improvement mechanism to the company and thus provided a clear understanding of where the research activities should focus to benefit the company.

5. RESEARCH RESULTS AND DISCUSSION

Semi-structured interview results provided a clear understanding of design management practices within the company and where the major challenges lie for improving performance. Several aspects of design management practice were discussed during the interviews. The results of this exercise and the triangulation with literature sources are presented below.

5.1 Nature of design

When asked to describe the process of design only a third of respondents identified the four main design activities of analysis, synthesis, evaluation and dissemination as described by Markus and Arch [27] albeit using varying terminology. They described the design process within the context of a project process. This would be expected, considering that it is the terminology they are comfortable with and use in the work environment. However, no respondent identified the iterative nature of design [28] and only one respondent identified an "appraisal" [27] activity as part of the design process.

Some interview comments suggested that company employees with a contracting background do not understand the process of design. Two interviewees with such a background were unable to provide an answer to the question. However, an interviewee with design experience demonstrated a similar inability. The analysis of interview results suggests that there is a need to improve the understanding of the very nature of the design process throughout the company. This is considered necessary by literature to be able to successfully achieve project objectives [29] and undertake the activity of design [30]. A structured and explicit design process may help to educate staff about the nature of the design process. It allows process participants to understand the process as a whole, their roles and responsibilities [24].

5.2 Standard design process definitions

The responses by interviewees when asked whether they were aware of any standard design process definitions are shown in Table 1. There is a general awareness (73%) of the RIBA Plan of Work [31]. This is to be expected as it has been available since the mid 1960's and therefore it is likely that many within the industry would be aware of it. Only one interviewee stated an awareness of another standard design process definition, a project process map produced by a project management group and believed it to be a "very effective way of representing the project". No interviewee was able to provide a detailed description of any standard design process definition such as the various stages of the RIBA Plan of Work.

response	number	percentage
No	3	20%
I am aware of RIBA plan of work	11	73%
I am aware of other standard process definitions	1	7%
I understand in detail a standard process definition	0	0%

Table 1: Knowledge of standard design process definitions

This line of questioning has highlighted that the company uses no consistent process for approaching the design phase of a project. It is claimed [32] that to be able to manage a process effectively it must be repeatable. The inconsistent way in which design is approached from project to project will therefore make management of the process difficult.

The provision of a structured and explicit design process within the company would provide the potential to establish a consistent approach to project design and also to reduce ambiguity in the scope of tasks to be undertaken [19].

5.3 Project design stages

Interviewees were asked to identify the stages of a project's design process and define when each started and finished including the activities that occur during each stage. Responses were mapped against four high-level design process definitions: The Process Protocol [24], the RIBA Plan of Work [31], the BAA Project Process [33] and the AMEC Project Process [34]. Figure 1 shows this mapping of interviewee responses. Only seven of the fifteen interviewees felt able to answer this question. Those that provided answers omitted some stages completely or described them using varying terminology. There were also inconsistent descriptions by interviewees of the activities to be undertaken at each stage.

Concept and scheme design stages were not identified by all interviewees and were sometimes described by different terms: tender and preliminary design were used to describe the scheme design stage, whilst scheme development was sometimes referred to instead of concept design. Detailed design was the only phase described consistently.

Currently, employees across the company describe project stages using varying terminology and do not have a common perception of the activities undertaken during each project stage. Without a common language, there is no hope of generating common aims and objectives within the process [35] as verbal communication can neither create sufficient understanding of a process between various parties nor define issues unambiguously [19]. It has been suggested [36] that if the activities that constitute design are not understood, it is not possible to manage design successfully.

An ordered approach to the design process is clearly essential if people are to work together effectively towards common goals [20]. A structured and explicit design process provides such an ordered approach with a common language and unambiguous description of tasks. This improved understanding of the design process will enable project teams to make more rational decisions at the right time and with a full understanding of the implications [36].

Process Protocol	RIBA (plan of work)	BAA Project Process	AMEC Project Process	Interview responses
			Business Consultancy	
Demonstrating the Need	Pre-Agreement	Inception	Inception	Design Brief Client Brief Stage Understanding and evaluate client business needs
Conception of Need	Inception			
Outline Feasibility	Feasibility	Feasibility	Feasibility	Feasibility study
Substantive Feasibility Study				
Outline Conceptual Design	Outline Proposals	Concept Design	Concept Design	Concept stage Concept design Scheme development Develop options
Full Conceptual Design	Scheme Design		Scheme Design	Tender design Scheme design Preliminary design
		Co-ordinated Design		
Co-ordinated Design, Procurement and Full Financial Authority	Detailed Design		Detailed Design	Detailed design
Production Information	Production	Production Information	Production Information	
	Tender Action			
	Project Planning			
Construction	Operations on site	Construction	Construction	
	Completion			
Operation and Maintenance	Feedback	Operations and Maintenance	Post Handover	As-built design
			Operations and Maintenance	
			Refurbishment	
			Decommissioning	

Figure 1 Interviewees view of the project process compared to standard project processes

5.4 Design management activities and processes

Activities that interviewees believed were part of the design management function are shown in Table 2. The interviewees identified many of the design management issues and activities that are considered significant [3, 4, 5, 6, 7]. It can therefore be concluded that the company understands the fundamental activities necessary to successfully address design management issues and problems, which may be attributed to experience of common difficulties during design. This triangulation also gives confidence in the knowledge of the company staff involved in the research and therefore the validity of the findings.

rank	activity	number	problem factors and roles identified in literature
1	design change management	12	change control process
2	design team leadership	12	erratic decision making/inadequacies in designers' technical knowledge
3	design planning	12	low confidence in preplanning design/unbalanced resource allocation
4	information flow	11	deficient or missing input information/information management
5	standard processes / framework	11	
6	programme / progress monitoring	10	manage progress and budget/manage approval process
7	client briefing/requirements capture	8	poor briefing
8	integrating design and construction	8	intergrated design and construction/feedback from site to design
9	interface management	8	lack of co-ordination between disciplines/interface management
10	project team structure	8	
11	value management	6	value management
12	risk management	5	risk analysis
13	buildability	5	buildability
14	design development / control	4	design development
15	tools and training	4	
16	decision control	2	lack of adequate documentation/design decision control
17	cultural issues	2	
18	CDM / Health and Safety	2	
19	team building	1	team building

Table 2: Interviewee's perceived design management activities compared against literature sources

5.5 Design management tools

The tools used by interviewees to manage the design process are shown in Figure 2. They range from meetings to financial control schedules. Other tools include information release schedules and milestone delivery dates. A programme of project design activities is the second most popular tool used by interviewees to manage the design but this used by only a third of the sample.

Figure 2 indicates the range of techniques deployed. Thirteen out of the fifteen interviewees used some structured method, but only five manage design with a combination of three or more of the tools and a further five use only one. Other than interviewees G, H and N, interviewees use few and differing tools to manage the design process. This indicates the company has no defined approach to design management, which may be hampering its design management performance.

rank	tool	interviewee															number
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	
1	meetings	x				x	x	x	x			x			x	x	8
2	project programme		x	x	x			x	x								5
3	information release schedule			x				x	x						x	x	5
4	electronic document management							x	x	x					x	x	5
5	design deliverable schedules							x	x				x		x		4
6	milestone dates					x	x			x							3
7	financial control schedule									x							1
	total number of tools	1	1	2	1	2	2	5	5	3	0	1	1	0	4	3	

Figure 2: Matrix of design management tools used by interviewees

The company needs a structured approach to design management incorporating tools to help manage the design process. There are tools, many already used in the construction industry, that can be adopted by the company. However, employees must be motivated to use any new technique otherwise its deployment is likely to fail. To generate enthusiasm users need to be trained and educated about the benefits, how and when to use tools and how to overcome barriers (cultural, organisational, process and technical) to uptake. How we focused on the tools appropriate for the company is explained in the methodology and the approach that is being used to encourage the use of these tools is discussed in the current research strategy section.

5.6 Design management strengths

Interviewees were asked to comment on design management activities they believed the company did well. The strengths identified were predominantly (83%) based on their technical skills (good technical design skills, create buildable solutions and understanding client needs) associated with the company's design consultant role. It is worth noting that two interviewees believed that no design management activities were carried out well. Generally, interviewees expressed a belief that design management practice within the company could improve significantly.

5.7 Design management improvement areas

Interviewees identified thirty-five separate design management issues they felt the company had often experienced. When triangulated with literature it became apparent that many of these issues were not attributable to just one cause but rather are the result of several factors. Therefore, the issues require a combination of techniques to address. For example, while the implementation of a structured and explicit design process is critical to addressing many of these, its application in isolation would not solve a single problem identified by the interviewees. Only when it is used in combination with other techniques will the company be able to overcome the design management difficulties it faces.

Table 3 indicates the relative importance to the company of implementing each improvement mechanism. The chart shows each improvement mechanism with an associated "importance weighting". The weighting of each improvement mechanism is explained in the methodology section.

improvement mechanism	importance weighting
structured and explicit design process	36
design planning	26
feedback systems	14
integrate design and construction	13
information flow management	7
understand/predict impact of a change	2
others	2

Table 3: Weighted improvement mechanisms

The cluster of improvement mechanisms that can help the company address the majority of design management challenges it faces are:

A. ***Structured and explicit design process*** - provide the team with a clear and explicit description of all the activities that will be carried out during a project, including their order, any dependencies and who should be involved.
B. ***Design planning -*** help the team plan a robust design in greater detail.
C. ***Integrate design and construction -*** help design and construction teams work together more effectively.
D. ***Information flow management -*** help the team to create a focus on design information rather than simply design deliverables.
E. ***Understand/predict impact of change -*** allow teams to understand and predict the impact of a potential design change.
F. ***Feedback systems -*** provide historical information to support the needs of other improvement mechanisms.

Focusing research on these six mechanisms would allow the company to successfully address twenty eight (80%) of the thirty five issues identified by interviewees and make significant contributions to the resolution of five (14%) further issues. A structured and explicit design process and improved design planning are the critical success factors that should be complemented by the other measures to deliver targeted improvement.

The seven issues contained within the "others" category in Table 3 have a collective importance weighting of 2. They do not represent core issues challenging the successful implementation of design management within the company and therefore will not be investigated further.

6. CURRENT RESEARCH STRATEGY

The research is now focusing on delivering advancements to the company in five of the improvement areas described above, namely:

- Structured and explicit design process
- Improved design planning
- Integrate design and construction
- Information flow management
- Understand/predict impact of design changes

The development of a feedback system was also identified in the earlier research as a potential improvement mechanism. However, this was considered to be outside the scope of the research and it is likely that the provision of a feedback system will be pursued centrally by the organisation in the near future.

We are now addressing the improvement strategy by launching a design management education and training initiative. This involves a series of workshops which examine critical aspects of the management of design and provide appropriate tools. A handbook has been developed containing training material including discussions on the barriers to effective design management, how to overcome them and a suite of twenty-one design management techniques. The latter were identified in the literature and research reviews and relate to the key improvement mechanisms shown above. They are grouped into four distinct yet inter-dependent categories:

- Planning - to help plan the design to satisfy all stakeholder requirements
- Co-ordination - to help co-ordinate design tasks and information
- Development - to help develop a design satisfying all stakeholder requirements

- Monitoring - to help monitor the progress of project parties

Workshop attendees are provided with an opportunity to discuss issues in the handbook as well as become familiar with the tools through worked examples and exercises. Project team support and a design management intranet site are being provided to ensure that the tools and practices are fully adopted within the company. Dissemination of good practice, on its own, is not sufficient to drive through change [37]. We will also gather feedback on the tools themselves and the impact of their application on projects.

Currently, the deployment of these tools and supporting training material is being monitored on a pilot project. Information is also being gathered on how individuals perceive each tool; the supporting training material and the effect of each tool on individual and project performance. The findings from this exercise will be used to refine the design management handbook and inform research understanding of design management within the construction industry.

From the deployment and testing of the tools and supporting implementation strategies we anticipate considerable company benefits and research learning. The main benefits are:

- suite of design management tools supported by training material
- company staff introduced to new ideas and tools
- company staff using new ideas and tools on projects
- improved project management (increasing efficiency and effectiveness)
- design management intranet site for support and organisational learning
- understanding the impact of tools on design management practices
- identifying the barriers to introduction and adoption of tools
- developing appropriate implementation strategies
- identifying improvements to existing techniques

7. CONCLUSIONS

This paper investigated how the barriers to managing the design process affect the success of an organisation undertaking design management. Many of the findings in literature were supported by the results of the case study. Triangulation of literature with case study results has led to several conclusions:

Like many organisations in the construction industry, the case study company operate with an unstructured design process. This has led to the use of varying terminology to describe stages and tasks in the process. If companies were to implement a more structured design processes more they might expect to experience the benefits of a common language to describe the process and an understanding of the tasks and responsibilities of each project party. From this it can be concluded that a structured design process can provide significant benefit by aligning the processes of project parties and providing an explicit road map to help manage each project. Therefore, this tool will be amongst those launched within the company.

Construction companies experience great difficulties in trying to manage the design process and from the case study it is apparent that company employees are aware of the issues they must address to manage the design process. From this situation it can be concluded that people need more than an understanding of the barriers to managing the process in order to overcome them. To successfully manage the design process people must be equipped with knowledge and tools aimed at overcoming the barriers to managing the process.

To improve design management performance the understanding of the very nature of the design process must be improved and more use should be made of the tools that are available to manage the design process. From the case study we know the type of tools (improvement mechanisms) that should be deployed to address the issues facing the company and wider industry. A structured approach to design management has been devised to benefit parties involved in managing the design process. This is currently being deployed within the case study company in the form of a design management education and training initiative. It aims to disseminate an understanding of the nature of the design process and provide tools focused on the key needs of the organisation.

8. ACKNOWLEDGEMENTS
The authors would wish to thank Engineering and Physical Sciences Research Council (EPSRC) which has provided the funding for this work. Also, the time and effort provided by interviewees within the company was invaluable in shaping the results of this research.

9. REFERENCES

[1] Kochan, A.: "Boothroyd / Dewhirst – quantify your designs". *Assembly Automation*, Vol. 11, No. 3, 1991, pp 12-14.

[2] Austin, S.A., Baldwin, A.N., Newton, A.J.: "A data flow model to plan and manage the build design process". *Journal of Engineering Design*, Vol. 7, No. 1, 1996, pp 3-17.

[3] Austin, S.A., Baldwin, A.N., Newton, A.J.: "Manipulating data flow models of the building design process to produce effective design programmes". *Proceedings of ARCOM Conference,* Loughborough, UK, 1994, pp 592-601.

[4] Cornick, T.: *Quality management for building design*, Butterworth, London, 1991,
pp 218.

[5] Hammond, J., Choo, H. J., Austin, S., Tommelein, I.D., Ballard, G.: "Integrating design planning, scheduling, and control with Deplan". *Proceedings of the 8th International Group for Lean Construction Conference*, Brighton, England, 2000.

[6] Koskela, L., Ballard, G., Tanhuanpaa, V-P.: "Towards lean design management". *Proceedings of the 5th International Group for Lean Construction Conference*, Gold Coast, Australia, 1997.

[7] Lafford *et al*: "Civil Engineering design and construction; a guide to integrating design into the construction process". *Funders Report C534*, Construction Industry Research and Information Association, London, 2001.

[8] Horner, R.M.W. and Zakieh, R.: "Improving construction productivity – a practical demonstration for a process based approach". *Internal publication*, Construction Management Research Unit, University of Dundee, 1998.

[9] Josephson, P. E. and Hammerlund, Y.: "Costs of quality defects in the 90's", *Report 49*, Building Economics and Construction Management, Chalmers University of Technology, 1996, pp 125.

[10] Baldwin, A.N., Austin, S.A., Hassan, T.M., Thorpe, A.: "Modelling information flow during the conceptual and schematic stages of building design", *Construction Management and Economics*, Vol. 17, No. 2, 1999, pp 155-167.

[11] Newton, A.J.: "The improved planning and management of multi-disciplinary building design", *PhD thesis*, Department of Civil and Building Engineering, Loughborough University, Leicestershire, 1995.

[12] Formoso, C.T., Tzotzopoulos, P., Jobim, M.S.S., Liedtke, R.: "Developing a protocol for managing the design process in the building industry", *Proceedings of the 6th International Group for Lean Construction Conference*, Guaruja, Brazil, 1998.

[13] Mohsini, R.: "Building procurement process: A study of temporary multi-orgainsations", *PhD thesis*, Universite de Montreal, Faculte l'Amenagement. Montreal, Canada, 1984.

[14] Mohsini, R. and Davidson, C: "Determinants of performance in the traditional building process", *Construction Management and Economics*, Vol. 10, No. 4, 1992, pp 343-359.

[15] Heath, T., Scott, D., Boyland, M.: "A prototype computer based design management tool", *Construction Management and Economics*, Vol. 12, 1994, pp 543-549.

[16] Egan, Sir J.: "Rethinking Construction: the report of the construction task force", *Department of the Environment, Transport and the Regions*, London, UK, 1998.

[17] Mitropoulos, P. and Tatum, C.B.: "Management-driven integration", *Journal of Management in Engineering*, January / February, 2000, pp 48-58.

[18] Love, P.E.D., Mandal, P., Smith, J., Li, H.: "Modelling the dynamics of design error induced rework in construction", *Construction Management and Economics*, Vol 18, 2000, pp 567-574.

[19] Karhu, V. and Lahdenpera, P.: "A formalised process model of current Finnish design and construction practice", *The International Journal of Construction Information Technology*, Vol. 7, No. 1, 1999, pp 51-71.

[20] Taylor A.J.: 'The Parallel Nature of Design'. *Journal of Engineering Design,* Vol.4, No.2, 1993, pp 141-152.

[21] Cole, E.: "Planning building design work", *Architectural Management*, Nicholson, M. (Ed), E& F. N. Spon, London, 1993.

[22] Baldwin, A.N, Austin, S.A., Thorpe, A., Hassan, T.: "Simulating the impact of design changes upon construction", *Proceedings of ARCOM Conference*, Loughborough, UK, 1994, pp 213-221

[23] Latham, Sir M.: "Constructing the Team", *HMSO*, London, 1994.

[24] Kagioglou, M. Cooper, R., Aouad, G., Hinks, J., Sexton, M., Sheath, D.: "Generic design and construction process protocol final report", *The University of Salford*, Salford, UK, 1998.

[25] Steele, J.L.: "The interdisciplinary conceptual design of buildings", *PhD thesis*, Department of Civil and Building Engineering, Loughborough University, Leicestershire, 2000.

[26] Brenner, M., Brown J., Canter D.: *The research interview: Uses and approaches*, Academic Press, London, 1985.

[27] Markus, T. and Arch, M., 1973, "Optimisation by Evaluation in the Appraisal of Buildings" *Value in Building*, Hutton, G.H. and Devonal, A.D.G. (Ed), Applied Science Publishers, London, 1973.

[28] Austin, S.A., Baldwin, A.N., Li, B., Waskett, P.: 'Integrating design in the project process', *Proceedings of the ICE: Civil Engineering*, Vol. 138, No. 4, 2000, pp 177-18.

[29] Abeysinhe, G. and Urand, D.: "Why use enactable models of construction processes", *Journal of Construction Engineering and Management*, November/December 1999, pp 437–447

[30] Maffin, D.: "Company Classification: A new Perspective on Modelling the Engineering Design and Product Development Process", *Journal of Engineering Design,* Vol. 6, No 4, 1995, pp 275-289.

[31] RIBA: "Plan of Work for design team operation", *RIBA Handbook*, Royal Institute of British Architects, London, 1973.

[32] Hinks, J., Aouad, G., Cooper, R., Sheath, D., Kagioglou, M., Sexton, M., 1997, "IT and the design and construction process: a conceptual model of co-maturation", *International Journal of Construction Information Technology*, Vol. 5, No. 1, 1997, pp 1-25.

[33] BAA Plc: "The Project Process: A guide to the BAA project process". *Internal publication*, BAA Plc, London, 1995.

[34] Vickery, O., Waskett, P.: "A framework for improving quality in construction through the implementation of structured project process", *Proceedings of CIBSE Conference*, Harrogate, UK, 1999.

[35] Root, D., Fernie, S., Baldwin, A.: "The languages of product and service-barriers to the integration of construction and design". *Proceedings of ARCOM Conference,* Liverpool, UK, 1999, Vol. 1, pp 181-190.

[36] Hedges, I.W., Hanby, V.I., Murray, M.A.P.: "A Radical Approach to Design Management". *Proceedings of CLIMA 2000 Conference,* London, 1993, pp 295-314.

[37] Frost, R.B.: "Why does industry ignore design science". *Journal of Engineering Design*, Vol. 10, No. 4, 1999, pp 301-304.

APPENDIX B   PAPER 2

Bibby, L., Bouchlaghem, N., Austin, S., 2002, "Delivering Learning and Tools to Improve Design Management in Practice", *Proceedings of CIB Conference on Measurement and Management of Architectural Value in Performance-Based Buildings*, Hong Kong, May 2002.

DELIVERING LEARNING AND TOOLS TO IMPROVE DESIGN MANAGEMENT IN PRACTICE

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Abstract

Difficulties in managing the construction design process are preventing the UK construction industry from delivering projects on time, to budget and to the specified quality. The paper reports on a research project being undertaken at a major UK civil and building design and construction company to develop and deploy a training initiative capable of making significant improvements to its design management performance and deliver benefits to many project stakeholders. It describes the development, content and deployment of training material and a suite of twenty-one design management tools to drive change throughout the organisation. The paper is likely to be of interest to those involved in design management and the development of tools and practices to help the industry improve design management performance.

Keywords: construction, design, management, industry practice, process, tools.

1. INTRODUCTION

In the construction industry, design is a key activity where the customer's needs and requirements are conceptualised into a physical model of procedures, drawings and technical specifications in a process defining up to 70% of the cost of the final product (Kochan, 1991). The design phase also has many interfaces with other processes (construction and procurement) and organisations (client, user representatives and regulatory bodies).

Historically, design was manageable with simple planning and management techniques. However, management of the design process has become more complex as a result of factors such as fast tracking and the increasing complexity of the fabric and content of buildings requiring enormous co-ordination effort, which rarely achieves its goals

(Austin, Baldwin and Newton, 1996). It is characterised by poor communication, lack of adequate documentation, deficient or missing input information, poor information management, unbalanced resource allocation, lack of co-ordination between disciplines and unco-ordinated decision making (Austin *et al*, 1996; Cornick, 1991; Hammond *et al*, 2000; Koskela *et al*, 1997; Lafford *et al*, 2001).

The cause of the majority of construction delays and defects can be related to poor design performance ((Horner and Zakieh, 1998), (Josephson and Hammerlund, 1996)) frequently creating problems that are more significant than those attributed to poor workmanship and site management (Baldwin *et al*, 1999). This scenario is very familiar to the company under investigation and is a major driver to improving design management performance.

The company recognises that it must improve the management of the design process and therefore will have to do this by ensuring that its personnel possess the understanding and skills to manage the complex and multidisciplinary construction design process. However, any change to current working practices must address a significant hurdle if it is to stand any chance of success: this is the existing company culture (Burnes, 1996). The prevailing culture (how personnel adapt to, and recognise, the need for change) is the most significant factor in trying to improve efficiency (Filson and Lewis, 2000). However, as construction is based on a culture which is fragmented, confrontational, has tough competition and lacks co-ordination (Mohamed, 1999) this cannot be changed easily or quickly (Clement, 1994).

This paper describes the development, content and deployment of a training initiative to improve management of the design process. The aim of this initiative is to disseminate an understanding of critical aspects of design management and a suite of twenty-one tools throughout a design and construction organisation. It is believed that this will enable the organisation to address the issues and take the actions necessary to manage the design process and deliver a design product which is co-ordinated, coherent and contains features to satisfy all stakeholders.

2. CASE STUDY

The company where the training initiative is being implemented is one of the top five civil and building design and construction companies in the UK with interests in PFI, design and build as well as traditional contracting. The company recognises it has to make a step change in how it is managing the design process in order to gain competitive advantage over its rivals. To deliver these changes a partnership of the company, Loughborough University and the Engineering and Physical Sciences Research Council (EPSRC) is supporting a research project on design management, as part of a four year Engineering Doctorate (EngD) Programme delivering changes to design management understanding and practices.

3. RESEARCH METHODOLOGY

To develop a credible training initiative relevant to practitioners an initial study was undertaken to determine the needs of company employees. This was based on a previous approach (Steele, 2000). The methodology comprised a state of the art review, review of current and recent research projects in the field, semi-structured interviews with company staff and triangulation of interview results with literature.

The state of the art review provided an up-to-date understanding of construction design management, revealed source material for the training initiative and helped formulate a framework for conducting the semi-structured interviews. The review of current and recent research projects in the field indicated where the research could focus to provide competitive advantage to the company while ensuring it did not duplicate any existing work.

The semi-structured interviews collected data from fifteen individuals (directors, project managers, construction managers, design managers and design engineers) relating to current design management practices and problems within the company. They were preferred to structured interviews, where respondents are offered a limited range of answers, which has the risk of leading to biased views. At the other extreme unstructured interviews can produce data that are both difficult and laborious to code and analyse. Good practice in conducting interviews was used in this research (Brenner, Brown and Canter, 1985). The interview results were categorised and triangulated with literature as a validation exercise. Triangulation also highlighted underlying causes and potential solutions to the problems identified by interviewees.

The interviewees identified a significant number of issues to address in current design management practice. Triangulation with literature revealed the underlying root causes and potential solutions for these issues. The solutions were generalised to a cluster of key improvement mechanisms to guide the content of the training initiative. They are:

- Structured and explicit design process;
- Improved design planning;
- Integration of design and construction;
- Information flow management; and
- Understand/predict impact of design changes.

A structured and explicit design process and improved design planning are the critical success factors that should be complemented by the other measures to deliver targeted improvement.

In determining the scope and content of the training initiative we have addressed common industry barriers to improving the management of the design process. Therefore, we consider the initiative as applicable and relevant to other organisations involved in the management of the design process.

4. PREPARATION OF TRAINING MATERIAL

The fundamental aim of the training initiative is to empower practitioners and motivate them to adopt new practices and tools, because any system that does not motivate the user will never be successfully implemented (Heath, Scott and Boyland, 1994). The training initiative has been prepared taking into account the barriers (cultural, organisational, process and technical) that exist to organisational change and the implementation of new tools in the construction industry. These barriers have been identified in literature (Freire and Alarcon, 2000; Frost, 1999) and include:

- Fragmented nature of design management tools;
- Many tools not sufficiently developed for industry application;
- Tools poorly deployed into industry practice;
- Couched in abstract terms unpalatable to industry;
- Overly complex representations of industry practice;
- Not focused on pragmatic outcomes; and
- Forces unwanted discipline on practitioners.

To make the training initiative interesting and motivating to practitioners it was vital to:

- Suitably developed for industry application;
- Carefully deployed within practice;
- Written in a language that practitioners could relate to;
- User friendly;
- Focused on pragmatic outcomes; and
- Not imposing unwanted discipline.

These rules guided the collection and compilation of material to achieve the following four objectives:

- To demonstrate practical and real benefits of design management to practitioners (benefits of design management);
- To raise awareness of the obstacles to effective design management and shape content of design management tools (barriers to design management);
- To identify effective design management practices and help shape content of design management tools (effective ways of managing the process); and
- To provide a framework of suitable tools associated with key improvement mechanisms. Tools cover all stages of the design process to promote good and consistent practices (design management tools).

Collecting information in this way ensured that it was direct, concise and relevant to practitioners. Once compiled it was important that the training delivery techniques made the information accessible and motivated users to adopt the ideas and tools presented. As such, the initiative comprises a range of implementation strategies to improve uptake in the organisation. These strategies include: a design management handbook, training workshops, team support and project monitoring.

5. DESIGN MANAGEMENT HANDBOOK

Findings from the state of the art review were grouped into ten chapters covering critical aspects of design management and a suite of twenty-one design management tools. The tools relate to the key improvement mechanisms identified in earlier research activities. To address concerns that many design management tools are fragmented (Freire and Alarcon, 2000) the research team focused on making the tools coherent and co-ordinated. Any synergies between the tools are clearly identified and to help locate where tools should be used in the design process they were grouped into types, giving four distinct yet inter-dependent categories. These were:

- Planning – help the strategic planning of activities and information flows;
- Co-ordination – assist management of activities and information on a daily basis;
- Development – help practitioners prepare a value focused design product that meets with all stakeholder requirements; and
- Monitoring – help practitioners check that design activities and information flows are occurring as planned and to prepare corrective action plans when progress is behind programme.

The format of the handbook has been designed to make it accessible and relevant to the needs of practitioners.

The handbook chapters have a standard format. Each chapter contains a “challenge” and an “objective”. The former indicates the importance of the chapter’s subject area to managing the design process and the latter explains what the reader should learn and be able to achieve after reading the chapter. These features aim to motivate practitioners to read the chapters and adopt ideas presented by demonstrating practical benefits of new approaches. Each chapter also contains a list of design management tools relevant to the subject area to make users aware of the tools applicable to address particular situations. The format of each chapter page in the handbook is illustrated by Figure 1.

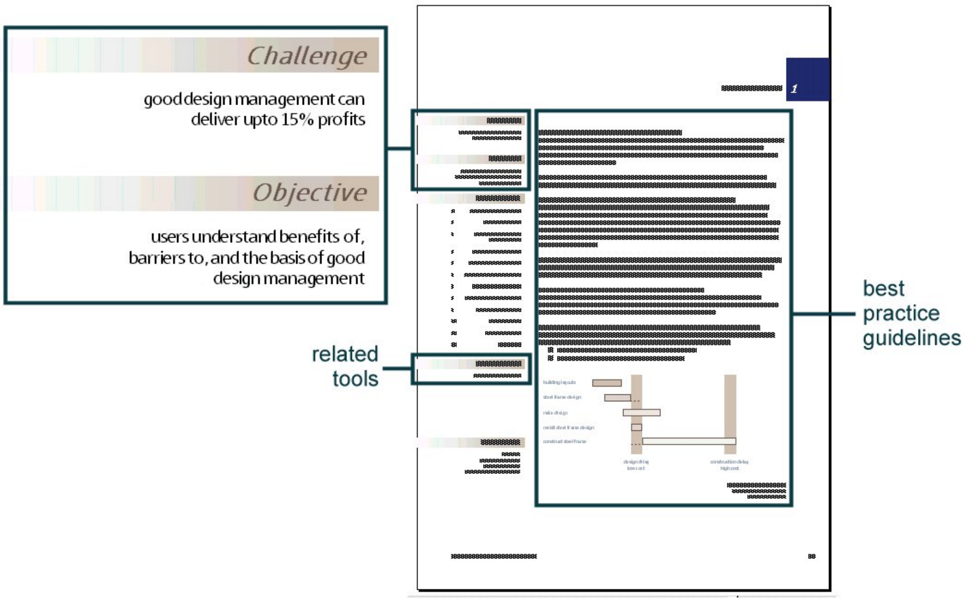

Figure 1: *Handbook chapter format*

The format of the design management tools' sections were standardised to aid reference, comparison and selection of tools. The set of toolsheets for each tool contains the following:

- Objectives – describes the intended purpose of the tool so users are clear of what the tool will help them achieve;
- Pre-requisites – describes documents and information required to apply the tool. This helps to ensure users have the correct information ready before they try to use the tool;
- Related tools – identifies other practices linked to the tool. This ensures that the toolbox is coherent and co-ordinated;
- Further information – research team contact information. Users are able to contact the team if they have queries relating to the application of the tool;
- Summary – short overview outlining what the tool does, where it is used and method of use. This way, users are clear on where and when to use the tool;
- Benefits and barriers – describes the benefits that practitioners should expect from using the tool, and barriers they should be aware of that may affect its performance. This section aims to help motivate practitioner to use the tool and also be able to remove the barriers to its application;
- Procedure - detailed description of the activities needed to apply the tool. This makes the operation of the tool transparent (Frost, 1999) and will ease their application into practice;
- Flowchart – abbreviated representation of the procedure in flowchart format. It summarises the key stages of the application of the tool. This is for users who have become familiar with the tool and need only check the outline procedure; and
- Supporting material – additional documentation to help users familiarise themselves with the tools and apply them in practice. These include templates,

examples and electronic versions of the tools. Inclusion of such material is necessary for practitioners to adopt new tools (Frost, 1999).

The format of the tool pages is illustrated by Figures 2 and 3.

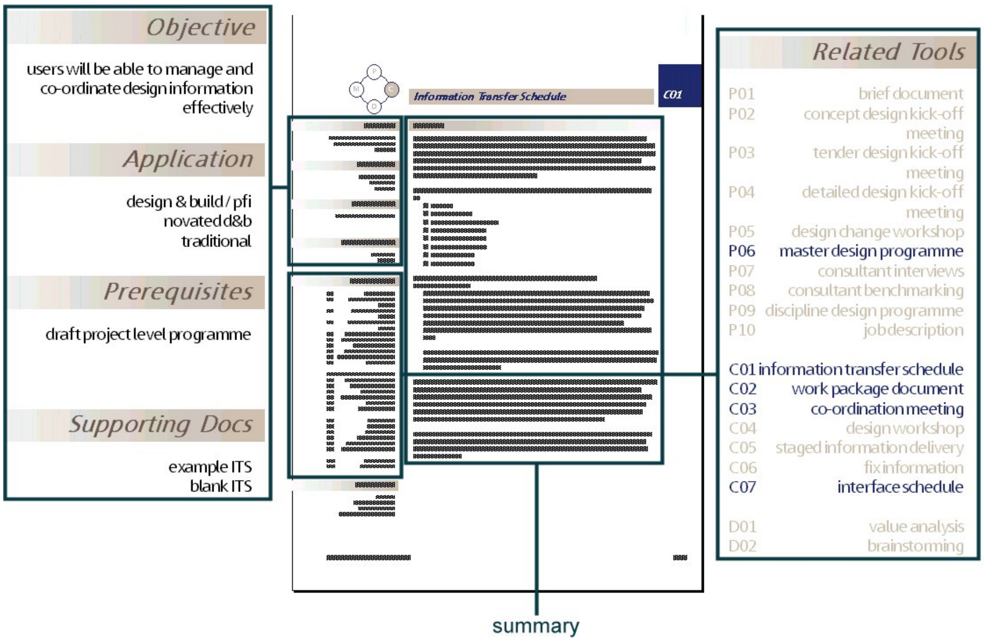

Figure 2: *Tool front page format*

A set of tool selection tables (one for each tool type) is provided in the handbook to aid practitioners select tools appropriate for their needs. In each table users can select tools by either referring to objectives they wish to achieve or issues they wish to address. This process is intended to help make the tools more accessible to those practitioners who are aware of the problems and issues of managing the design process but are unaware of the approaches they need to take to resolve such issues.

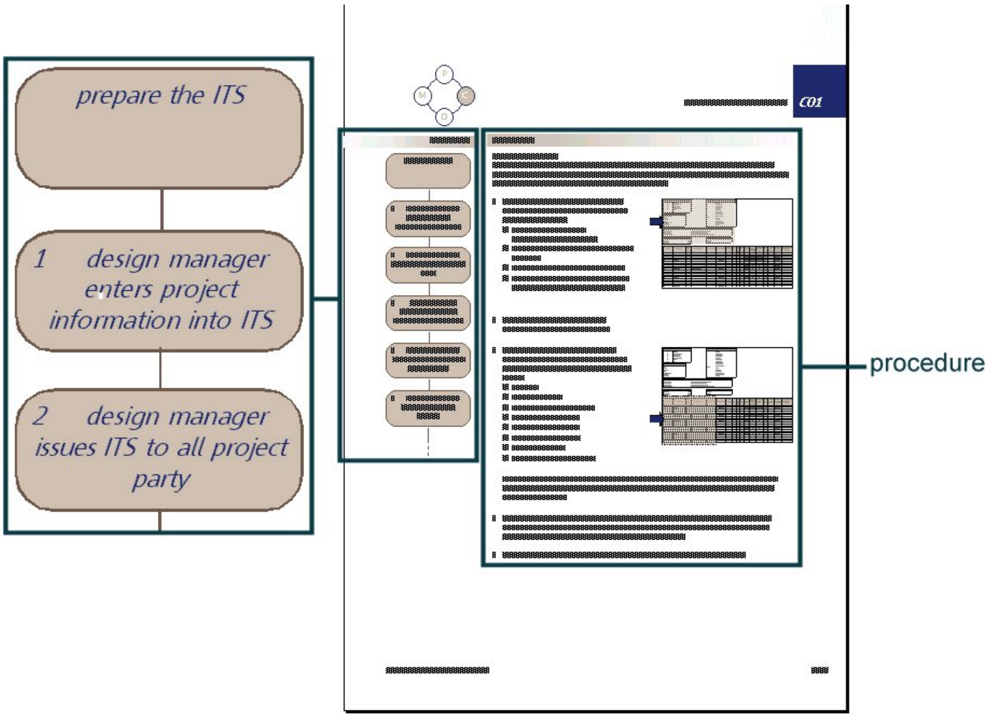

Figure 3: *Tool procedure and flowchart*

6. TRAINING WORKSHOPS

The training material is principally being disseminated throughout the organisation using a series of training workshops. These are meant to deliver understanding of critical aspects of design management and support the application of tools contained in the handbook. This includes ten workshops; each covers a specific design management topic, and introduces best practice ideas and associated tools. The starting point of the workshops is to engender a consensus amongst practitioners that the existing methods are no longer delivering the desired results. This is a key factor in implementing organisational change (Filson and Lewis, 2000).

Workshop attendees are provided with an opportunity to discuss the barriers to design management, how to overcome them and become familiar with suitable tools through worked examples and exercises. This interaction between the research team and workshop attendees is vital to the success of the initiative. It allows participants the opportunity to influence the content of their learning and the practices they will adopt, thereby allowing them to be involved in the process of organisational change (Mohamed, 1999). It also ensures that there is a high level of commitment from participants, which is key to a successful change programme (Kettley, 1995). The workshop material is being delivered using a combination of techniques to maintain this commitment and interest: presentation; discussion; exercise; worked examples and problem solving.

7. TEAM SUPPORT

Implementing organisational change is a long-term activity, with many experts agreeing that it is a long-term process (Williams, Dobson and Walters, 1993). We anticipate that additional support will be required following the first delivery of the training workshops. This will be provided by team support, which comprises:

- Help line – practitioners concerned with any of the training initiative content will be able to contact the research team directly to deal with any queries or problems;
- Project strategies – advice will be given to project teams to devise appropriate design management approaches and techniques to address specific project circumstances;
- Tutorials – for those not attending the initial training workshops, the research team will facilitate individual and group workshops; and
- Team integration – the research team will support project teams in putting tools and techniques into practice through membership in the project team.

All these activities, as well as helping to implement the new practices and tools into the organisation will be a useful forum in which to collect practitioners views on the training initiative and its effect on individual and project performance.

8. PROJECT MONITORING

Along with demonstrating the effect of the training initiative on design management performance we are monitoring the impact of the initiative on individual and project performance as an intrinsic part of improving design management in the organisation. It is essential that benefits are monitored to reinforce the desired change (Galpin, 1996) to those affected by the change process and to determine if yet further improvements can be made (Filson and Lewis, 2000). The methods for project monitoring are explained in the current research strategy.

9. CURRENT RESEARCH STRATEGY

The training initiative is currently being trialed within the organisation in two ways:

- training workshops delivered across the organisation; and
- implementation of the tools monitored on a specific project.

Whilst we are currently implementing the initiative principally within the organisation, the case study project involves the wider design supply chain that exists within the project team. This includes clients, designers, and specialist sub-contractors, who all have a significant input into the design process. The sharing of this initiative with project parties allows all parties to understand the importance of design management, their role in the process and provides an ordered approach to management of the process throughout the project team. This is critical for teams that must work together effectively towards common goals (Taylor, 1993). It will also ensure that the tools and practices will be rigorously tested through exposure to a global project team.

10. ORGANISATIONAL ROLL-OUT

The training initiative is being delivered to all levels of the organisation's management teams covering approximately 300 personnel. Directors and managers (construction, procurement, commercial and design) are receiving training on the critical aspects of design management and design managers are receiving additional training on the operation and implementation of the suite of design management tools. The research team and the company considered it was very important that design management training was made available to the whole management team. In order to succeed, design management requires a range of professionals to collaborate and a significant barrier to successful collaboration is a lack of understanding of the motives and actions of others. If professionals that work with design managers understand the process of design, key barriers to design management, and the actions of the design manager, this will enable them to support the design manager and collaboratively manage the design process.

11. PROJECT IMPLEMENTATION

The design management training initiative is also being trialed on a specific project to evaluate in detail the effects of the initiative on design management performance. The case study project is the design and construction of a £28m private finance initiative (PFI) hospital in Coventry, England. The company has responsibility for design management and construction. There are four principal design disciplines as well as several specialist sub-contract designers involved in the project. Management of these parties will require a considerable effort and therefore is a comprehensive test of the design management practices and tools that are being trialed.

Each tool is being launched on the project at appropriate points in the design process in order to deliver the knowledge when it is most likely to be needed and to avoid overloading practitioners with too many tools at once. Planning and co-ordination tools have been launched during the planning phase. Later in the process development and monitoring tools will be introduced.

Dissemination of good practice, on its own, is not sufficient to drive through change (Frost, 1999). We are gathering feedback on the tools themselves and the impact of their application on projects. We are using three methods to monitor the implementation of the tools and the effect they have on design management performance: structured questionnaire, semi-structured interviews and performance data collection. The structured questionnaire and semi-structured interviews are being used to gather feedback on:

- which tools are being taken up and why;
- which tools are not being taken up and why;
- the barriers to implementing new design management tools in industry;
- users perceptions of training initiative; and
- user perception of applicability and performance of design management tools.

The collection of performance data will focus on:

- the impacts of the training initiative on individual performance; and

- the impacts of the training initiative on project performance.

We are also collecting similar performance data on control projects where no structured design management approaches or tools have been implemented as a comparison of the effects of the initiative and tools.

12. ANTICIPATED BENEFITS

We anticipate that the findings from this exercise will be of interest to the wider industry and will inform research understanding of design management and its implementation within the construction industry. The potential benefits to the industry and research learning are:

- suite of design management tools supported by training material;
- company personnel introduced to new ideas and tools;
- company personnel using new ideas and tools on projects;
- improved management of the design process (increasing efficiency and effectiveness to deliver a co-ordinated, timely and value focused design);
- self learning exercises and online support to improve organisational learning of appropriate design management tools and techniques;
- an understanding of the impact of tools on design management practices;
- identifying the barriers to introduction and adoption of new design management tools in industry;
- appropriate implementation strategies to help launch new design management tools; and
- identifying improvements to existing design management tools and techniques.

13. FUTURE RESEARCH STRATEGY

The comments, views and data collected from the implementation of the training initiative will be used in the next phase of the research to modify the contents and format of the training material and tools to suit the needs of practitioners. This feedback from practitioners is vital to engaging those affected by organisational change and thus ensuring success of the training initiative. Genuine involvement of those affected by organisational change is the key factor in its success or failure. Genuine participation is shown to succeed, whilst non-genuine (pseudo-participation) is shown to fail (White, 1979).

We intend to use the knowledge gained from current research activities to develop and implement some “new” tools that we anticipate will require further organisational change to successfully implement them. One of these is a design management process model to further improve co-ordination and clarity in the construction design process.

The learning from the current phase of research will also be used to develop an intranet site to help drive the process of organisational change within the company. This will be available through the company intranet and will include:

- a self learning version of the training initiative;

- an electronic version of the design management handbook;
- electronic versions of the tools that are software-based available to download; and
- a discussion forum to promote interest in design management within the company and for practitioners to share design management ideas and success stories.

14. CONCLUSIONS

This paper has reported on the development, content and deployment of a design management training initiative within a major UK civil and building design and construction company which has led to some interesting conclusions.

The fundamental aim of the training initiative is to bring about a culture change by engendering a consensus amongst practitioners that existing methods are no longer delivering the desired results and then to convince them that other tools and techniques are appropriate to their requirements. To do this we have prepared the training material and tools by considering the barriers (cultural, organisational, process and technical) that exist to organisational change and the implementation of new tools in the construction industry. This has had a significant affect on the style, content and format of the training initiative in that we have:

- provided good practice guidelines integrating the activities of all professionals during the design process using language and formats relevant to practitioners;
- prepared the workshops and handbook with a style and format accessible to practitioners;
- provided tools that are useful, practical and easy to use; and
- provided a range of training methods to address the needs of a range of professionals.

In conclusion it is vital when trying to implement new ways of working into industry practice to take account of the barriers (not least the prevailing organisational culture) that exist and devise a strategy to overcome them if it is to be adopted in practice.

Design management while typically the role of one management function can be significantly affected by the actions of others. They must be educated about the importance of the design process in delivering value to the whole project, how the way they work affects the design process, how they can contribute to the design and consequentially the whole project process. Therefore, implementation of a design management tool or practice must include and educate at all levels within an organisation and project team to ensure it is taken up in practice.

Implementing organisational change is a long-term activity, with many experts agreeing that it is a long-term process. Any change to design management practices must address many significant barriers, not least the underlying company and construction industry culture. Therefore, it must accessible to a range of professionals who have an influence on the design process. In conclusion, improving design management in practice is a long-term activity where the deployment effort must be sustained and varied to drive the required change and meet the training needs of the range of professionals involved in the process.

15. ACKNOWLEDGEMENTS

The authors would wish to thank Skanska UK Building and the Engineering and Physical Sciences Research Council (EPSRC), which have provided the funding for this work through the Centre for Innovative Construction Engineering at Loughborough University.

16. REFERENCES

Austin, S.A., Baldwin, A.N., Newton, A.J. 1996, "A data flow model to plan and manage the build design process", *Journal of Engineering Design*, Vol. 7, No. 1, pp 3-17.

Austin, S.A., Baldwin, A.N., Newton, A.J. 1994, "Manipulating data flow models of the building design process to produce effective design programmes", *Proceedings of ARCOM Conference,* Loughborough, UK, pp 592-601.

Baldwin, A.N., Austin, S.A., Hassan, T.M., Thorpe, A. 1999, "Modelling information flow during the conceptual and schematic stages of building design", *Construction Management and Economics*, Vol. 17, No. 2, pp 155-167.

Brenner, M., Brown J., Canter D. 1985, *The research interview: Uses and approaches*, Academic Press, London.

Burnes, B. 1996, *Managing change: A strategic approach to organisational development*, Pitman, London.

Clement, R. 1994, "Culture, leadership and power: the keys to organisational change", *Business Horizons*, January/February.

Cornick, T. 1991, *Quality management for building design*, Butterworth, London, pp 218.

Filson, A. and Lewis, A. 2000, "Cultural issues in implementing changes to new product development process in a small to medium sized enterprise (SME)", *Journal of Engineering Design*, Vol. 11, No. 2, pp 149-157.

Freire, J. and Alarcon, L.F. 2000, "Achieving a lean design process" in *Proceeding of the 8th International Group for Lean Construction Conference*, Brighton, England.

Frost, R.B. 1999, "Why does industry ignore design science", *Journal of Engineering Design*, Vol. 10, No. 4, pp 301-304.

Galpin, T. 1996, "Connecting culture to organisational change", *HR Magazine*, March.

Hammond, J., Choo, H. J., Austin, S., Tommelein, I.D., Ballard, G. 2000, "Integrating design planning, scheduling, and control with Deplan" in *Proceedings of the 8th International Group for Lean Construction Conference*, Brighton, England.

Heath, T., Scott, D., Boyland, M. 1994, "A prototype computer based design management tool", *Construction Management and Economics*, Vol. 12, pp 543-549.

Horner, R.M.W. and Zakieh, R. 1998, "Improving construction productivity – a practical demonstration for a process based approach", *Internal publication*, Construction Management Research Unit, University of Dundee.

Josephson, P. E. and Hammerlund, Y. 1996, "Costs of quality defects in the 90's", *Report 49*, Building Economics and Construction Management, Chalmers University of Technology, pp 125.

Kettley, P. 1995, "Is flatter better? Delayering the management hierarchy", *The Institute of Employment Studies, Report 290*.

Kochan, A. 1991, "Boothroyd / Dewhirst – quantify your designs", *Assembly Automation*, Vol. 11, No. 3, 1991, pp 12-14.

Koskela, L., Ballard, G., Tanhuanpaa, V-P. 1997, "Towards lean design management" in *Proceedings of the 5th International Group for Lean Construction Conference*, Gold Coast, Australia.

Lafford *et al*. 2001, *Civil Engineering design and construction; a guide to integrating design into the construction process*. *Funders Report C534*, Construction Industry Research and Information Association, London.

Mohamed, S. 1999, "What do we mean by construction process re-engineering?", *International Journal of Computer Integrated Design and Construction*, Vol 1, No 2, pp 3-9.

Steele, J.L. 2000, *The interdisciplinary conceptual design of buildings,* PhD thesis, Department of Civil and Building Engineering, Loughborough University, Leicestershire.

Taylor A.J. 1993, "The Parallel Nature of Design", *Journal of Engineering Design,* Vol.4, No.2, pp 141-152.

White, K. 1979, "The Scanlon Plan: causes and correlates of success", *Academy of Management Journal*, Vol. 22, June, pp 292-312.

Williams, A., Dobson, P., Walters, M. 1993, *Changing culture: New organisational approaches*, Second Edition, Institute of Personnel Management, London.

APPENDIX C PAPER 3

Bibby, L., Bouchlaghem, D., and Austin, S., 2003a, "Design Management in Practice: Testing a Training Initiative to Deliver Tools and Learning", Accepted for Publication in *Construction Innovation,* Vol. 3, No. 4, December 2003.

DESIGN MANAGEMENT IN PRACTICE: TESTING A TRAINING INITIATIVE TO DELIVER TOOLS AND LEARNING

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ABSTRACT: Drives to improve industry performance are being hindered by difficulties in managing the construction design process and preventing the UK construction industry from delivering projects on time, to budget and to the specified quality. The paper reports on a research project at a major UK civil and building design and construction company to develop and deploy a training initiative capable of making significant improvements to its design management performance and deliver benefits to many project stakeholders. It describes the development, content and trialing of the training material and a suite of twenty-one design management tools to drive change throughout the organisation. The paper is likely to be of interest to those involved in design management and the development of tools and practices to help the industry improve design management performance.

Keywords: construction, design, management, industry practice, process, tools, training.

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1. INTRODUCTION

In recent years efforts to improve the performance of the UK construction industry have shown an increasing interest in management of the design process and its integration with other project processes. One catalyst has been Egan *et al* (1998), who stated that to deliver greater value to its clients the design, procurement and construction operations need to be an integrated process. As design and build type projects are seen as a means to bring the processes together (Moore and Dainty, 1999) the private finance initiative (PFI) and design and build (D&B) procurement strategies have become widely used in recent years. This trend is unlikely to falter. The UK Government, as a major industry client, now assumes that some form of D&B procurement will be used on its projects unless a compelling case can be made for using a traditional procurement route (Office of Government Commerce, 2002). Furthermore, recent targets set by the Strategic Forum for Construction aim to increase the use of integrated project teams and supply chains to 20% of projects (by value) by the end of 2004, rising to 50% by the end of 2007 (Egan *et al*, 2002).

As a result of the drive away from traditional procurement routes contractors have found themselves with an increasing responsibility for control of a process they have had little experience in managing. They now have to adapt accordingly. The learning curve is steep, not least because many projects must now be delivered fast track while co-ordinating the increasingly complex fabric and content of buildings (Austin *et al*, 1996). In an effort to accelerate this learning, both industry leaders and SMEs (small to medium sized enterprises) have collaborated in projects that aim to manage the integration of teams during the design phase such as the Analytical Design Planning Technique (Austin et al, 1999), Integrated Collaborative Design (Austin et al, 2001), and Teamwork2000 (Business Round Table, 2002). Clearly, management of the project team during the design phase is a key issue for the UK construction industry which organisations must address.

A top four civil and building design and construction company with interests in PFI, Prime Contracting, D&B as well as traditional contracting is adapting to the changing UK construction market. For the past three years, through a partnership with Loughborough University and the Engineering and Physical Sciences Research Council (EPSRC), it has been addressing its approach to design management. A training initiative has developed out of this partnership to deliver critical thinking on design management and a suite of twenty-one tools. This paper describes the development, content and trialing of the initiative within the organisation.

While the training initiative was undertaken to suit the needs of a major D&B contractor, its development was influenced by best practice within and outside the industry, as well as common barriers identified in literature (Bibby et al, 2002). Hence, the lessons learned from work reported in this paper should be widely applicable to those in the industry involved in design management and the development of tools and practices to help the industry improve design management performance. Whilst the findings are based on a single organisation, the work carried out represents a significant step forward for the industry in developing strategies to deliver improvements to design management performance.

2. RESEARCH METHODOLOGY

The research presented in this paper sought to establish and test a training initiative capable of teaching the employees of a major UK contractor how to effectively manage the design process. The methodology comprised: a state of the art review to prepare the training initiative; a review workshop; and a questionnaire and structured interviews to investigate the effectiveness of the dissemination in changing current practice.

The state of the art review guided the format of the initiative by identifying similar work in the construction industry. It also helped shape the content by providing an up-to-date understanding of design management, the barriers that must be addressed and revealed source material from which practices and tools were developed.

The review workshop was held over two days at a hotel near London with the purpose of assessing the format and content and delivery of the training initiative. Fourteen company employees (seven design managers; four project managers; two commercial directors and one planning manager) with a particular interest in design management were selected to take part. A week prior to the workshop each attendee was provided with a copy of the design management handbook for review. The proposed training material was presented section-by-section in the workshop and then critically appraised in terms of the effectiveness of the delivery and user friendliness of the tools and practices. Comments made by workshop attendees were recorded for later compilation and analysis with questionnaire results.

The structured questionnaire prepared following good practice (Race, 2001; Fellows and Liu, 1997) was issued to collect more detailed views of the workshop attendees on the content and delivery of the training initiative. It was issued after the review workshop with returns requested three weeks later. This allowed attendees some time to reflect on the content and delivery of the design management handbook and training workshop. Twelve of the fourteen (86%) workshop attendees returned completed questionnaires.

The questionnaire asked respondents to rate aspects of the training initiative using a five point rating scale. They were also given the opportunity to make open comments on each aspect of the training initiative. The results were compiled with the comments made during the review workshop to establish whether the training initiative was capable of disseminating effective design management practice.

Approximately 300 personnel, covering all project team members (construction, procurement, commercial and design), are receiving training on the critical aspects of design management and their involvement in the process. Design managers are receiving additional training on the operation and implementation of the suite of design management tools. The company and research team believe it is vital that the training is given to all the management teams. In order to succeed, design management requires a range of professionals to collaborate and a significant barrier to this is a lack of understanding of the motives and actions of others. If professionals that work with design managers understand the process of design, key barriers to design management and the actions of the design manager, then they should be better able to support the design manager and manage the design process collaboratively.

3. WHY A TRAINING INITIATIVE?

Research to improve design management performance of a major UK construction company has required many questions to be answered. The first was: “Is a training initiative the right way to improve design management in the organisation?” Previous research (Bibby *et al*, 2002) established that the understanding of the very nature of the design process had to be improved and employees provided with practical tools to manage the process. Therefore, a training initiative, which provided such tools and learning, was seen as the most appropriate means to improve design management within the company.

4. WHAT MAKES PRACTITIONERS PARTICIPATE IN TRAINING?

The training initiative must be capable of motivating practitioners to adopt new practices and tools presented in the initiative, because without this desire the material would never be successfully implemented (Heath *et al*, 1994). Therefore, barriers that exist to the implementation of new tools in the construction industry must be addressed by the training content and format. There are many criticisms levelled at design management tools developed for industry. They are fragmented, insufficiently developed, poorly deployed and couched in abstract terms. Moreover, as they often show an overly complex representation of industry practice they are not focused on pragmatic outcomes and force an unwanted discipline on practitioners. (Freire and Alarcon, 2000; Frost, 1999). Knowledge of such difficulties was central to the production of an effective, user-friendly and pragmatic training initiative that would motivate practitioners.

5. WHAT SHOULD THE TRAINING CONTAIN?

There were several issues that had to be considered when collecting training material. Previous research (Bibby *et al*, 2002) had identified five key improvement issues that the company must address to improve design management performance (structured and explicit design process; improved design planning; integrated design and construction; information flow management and ability to understand / predict impact of design changes). It was also important to motivate practitioners to use new practices and tools and be realistic about what each can achieve. Therefore, literature collection was based on four key areas: design management tools; effective ways of managing the process; benefits; and barriers to design management. Collecting information in this way ensured that it was direct, concise and relevant.

6. HOW SHOULD TRAINING BE PRESENTED?

Discussions were held with the organisation to establish an appropriate means of presenting the wealth of collected material. It was decided that the core of the initiative should be a handbook or manual containing practical ideas and tools that could be easily implement. However, the company and research team felt that this alone would be insufficient to bring about significant change and therefore the handbook was supported by a training workshop disseminating the tools and ideas to the company employees.

6.1 Design Management Handbook

The outputs of similar projects (Thomson and Austin, 2001; Austin *et al*, 2001) were consulted to help present the content in a user-friendly format. From this review the core format of the handbook was created: ten chapters each covering a critical aspect of design management practice followed by a suite of twenty-one design management tools (Table 1). A design management tool is assumed to be any procedure, standard document or schedule that could support the management of the design process. The tools were grouped into four distinct yet inter-dependent categories: planning, co-ordination, development and monitoring to help identify where and when they should be applied: planning tools help the strategic planning of activities and information flows; co-ordination tools the daily management of activities and information; development tools help prepare a value-focused design that meets stakeholder requirements; and monitoring tools help check that design activities and information flows are occurring as planned and to plan corrective action when progress is behind programme.

handbook section	topics covered	tools provided
1 Design management	The need for and what is design management? Nature of the design process Why current design management goes wrong How can we better manage the design process?	
2 The design process	Nature of the process Involve parties at the right time Allow adequate design time Engender common design process	
3 Stakeholders objectives, briefs and tasks	The need to, barriers to and incorporating stakeholder needs in the design	P01 Brief document P02 Concept design kick-off meeting P03 Scheme design kick-off meeting P04 Detailed design kick-off meeting
4 Managers and structures	The need for, barriers to, qualities of and training good design managers suitable organisational structure	
5 Selecting team members	Importance of the team, necessary relationships and attitudes, skills and competencies	P07 Consultant benchmarking P08 Consultant interviews
6 Planning the design process	The need for, barriers to and planning the design process	P06 Master design programme
7 Ensuring design delivery	The need for, barriers to and effective design delivery	C01 Information transfer schedule C02 Work package document C03 Co-ordination meeting M01 Progress report M02 Progress meeting
8 Managing information flow	The need for, barriers to and effective information flow management	C04 Design workshop C05 Staged information delivery C06 Fix information
9 Developing the design	Barriers to and the process of design development	D01 Value analysis D02 Brainstorming D03 Decision matrix D04 Task force meeting D05 Design guide document
10 Design changes	The effect of, barriers to and managing design change proposals	P05 Design change workshop

Table 1: Design management handbook contents

The handbook chapters have a standard format (Figure 1), each containing a "challenge" and "objective". The former indicates the importance of the subject area and the latter explains what the reader should learn and be able to achieve. Each chapter also contains a list of relevant tools. These features aim to motivate practitioners to read the chapters and adopt ideas presented by highlighting practical benefits.

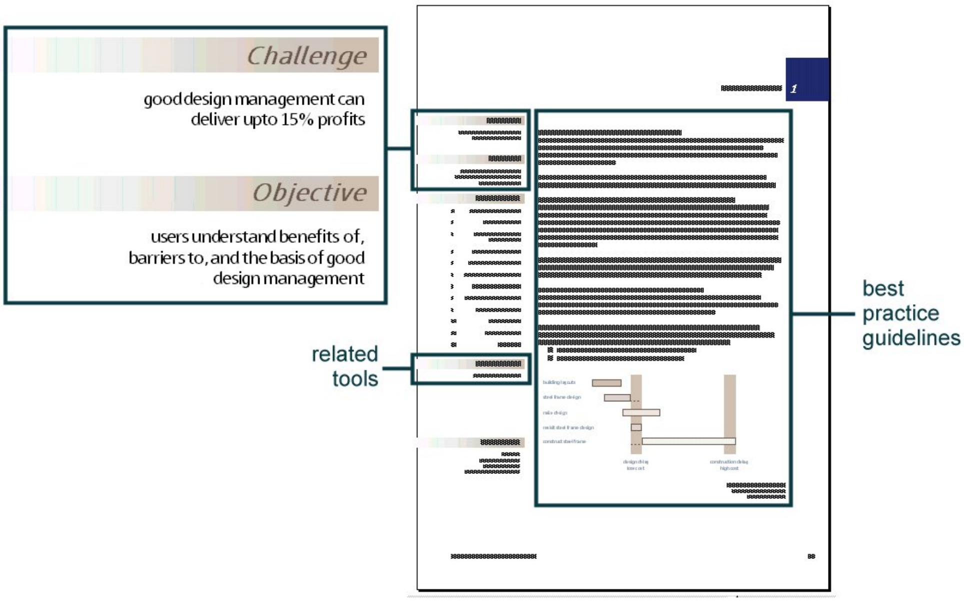

Figure 1: Handbook chapter page format

The design management toolsheets were also standardised to aid reference, comparison and selection of tools. The standardised format also helped ensure a complete tool was presented to practitioners. Many techniques identified in the literature were incomplete and lacked the detail that is necessary for application. For example, some use academic language, have unclear process steps and do not explain who should use them or when they should be applied. Others lacked supporting documents such as examples and blank templates. The standard format was very useful in helping modify and expand the content to provide comprehensive and practical tools suited to the needs of industry. The toolsheet sections and the reasons for their inclusion are shown in Figure 2, together with examples of tool pages in Figures 3 and 4.

toolsheet section	reason for inclusion
Objectives	Describes the intended purpose of the tool so users are clear of what the tool will help them achieve.
Pre-requisites	Describes documents and information required to apply the tool. This helps to ensure users are able to use the tools without delay.
Related tools	Identifies other practices linked to the tool. Synergies between any tools are clearly identified to address concerns that many design management tools are fragmented (Freire and Alarcon, 2000). Ensures the toolbox is co-ordinated and coherent.
Further information	Research team contact information. Users are able to contact the team if they have queries relating to application of the tool.
Summary	Short overview outlining what the tool does, where it is used and method of use. This way, users are clear on where and when to use the tool.
Benefits and barriers	Describes the benefits that practitioners should expect from using the tool, and barriers they should be aware of that may affect its performance. This section aims to help motivate practitioner to use the tool and also be able to remove barriers to its application.
Procedure	Detailed description of the activities needed to apply the tool. This makes the operation of the tool transparent (Frost, 1999), easing their application into practice.
Flowchart	Abbreviated representation of the procedure in flowchart format. It summarises the key application stages of the tool. This is for users who have become familiar with the tool and need only check the outline procedure.
Supporting material	Additional documentation to help users familiarise themselves with the tools and apply them in practice. These include templates, examples and electronic versions of the tools. Inclusion of such material is necessary for practitioners to adopt new tools (Frost, 1999).

Figure 2: Tool standard format

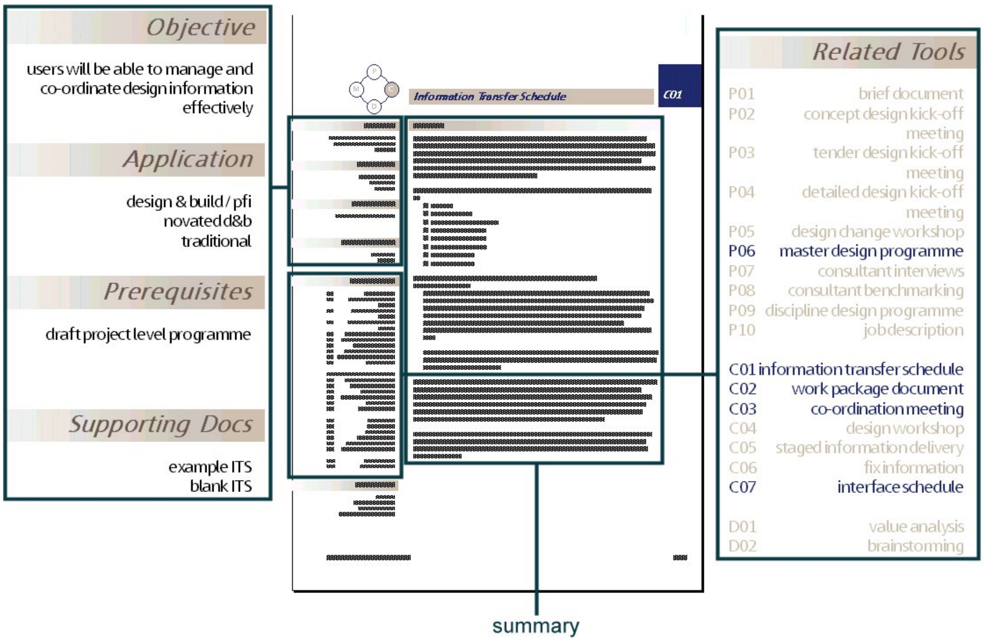

Figure 3: Tool front-page format

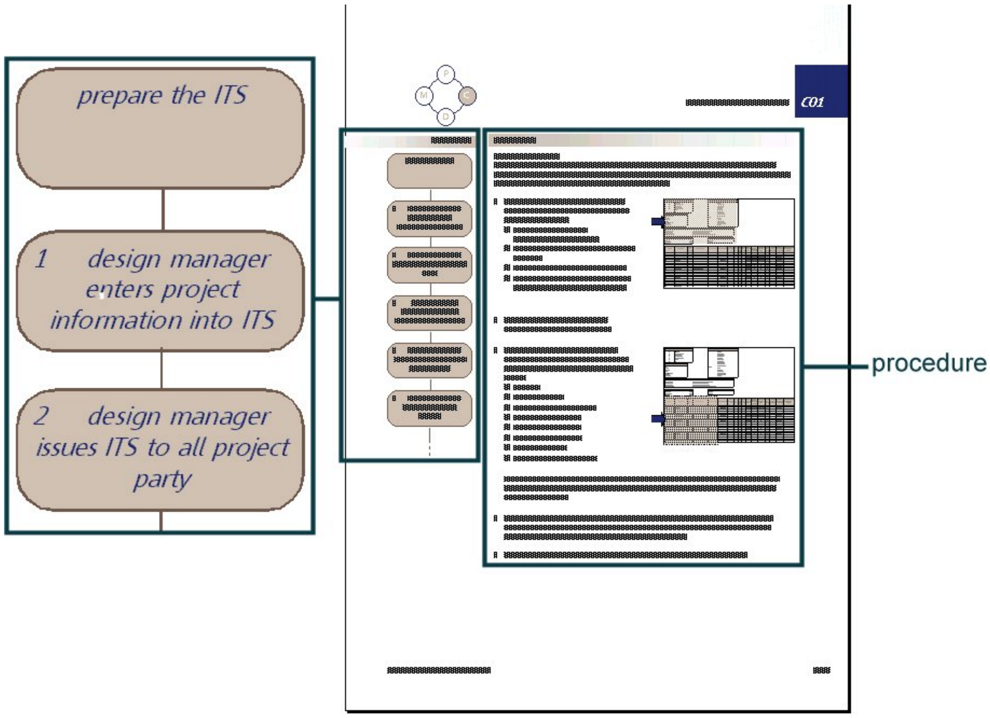

Figure 4: Tool procedure and flowchart

A set of four tool selection tables (one for each tool type) was also provided in the handbook to help practitioners select tools appropriate for their needs by referring to objectives they wish to achieve or problems they wish to overcome. The tables were designed to help individuals who recognise the problems and issues of managing the design process but are uncertain how they should resolve them.

6.2 Training workshop

The ideas, practices and tools contained in the handbook were developed into ten training modules each relating to a chapter in the handbook. The workshop material is delivered using a combination of techniques to maintain commitment and interest, including presentations, discussions, worked examples and problem solving exercises. This allows trainees the opportunity to discuss the barriers to design management, how to improve and to become familiar through worked examples and exercises. This interaction between the research team and trainees is vital to the success of the initiative for two reasons. It allows participants to form a consensus about which of their current practices are no longer working and ensures that there is a high level of commitment from participants. These are both key factors in promoting change (Filson and Lewis, 2000; Kettley, 1995).

7. FEEDBACK

The results from the review workshop and questionnaire provided clear indications of the capability of the training initiative to improve design management understanding and practice of a major UK civil and building design and construction company.

7.1 The Handbook

The reactions of workshop attendees to the handbook were very encouraging. They were asked whether the handbook had a clear and logical format, was easy to read and understand, covered design management in sufficient detail and gave them a good understanding of the subject (Table 2).

design management handbook….	has a clear and logical format	is easy to read and understand	covered design management in sufficient detail	gave me a good understanding of the subject
	%	%	%	%
strongly disagree	0%	0%	0%	0%
disagree	0%	8%	8%	0%
neutral	8%	17%	17%	17%
agree	83%	67%	67%	50%
strongly agree	8%	8%	8%	33%

Table 2: Review of Design Management Handbook

The results suggest that the handbook has a clear and logical format which is easy to read and understand. This is reflected in comments that the handbook was well laid out, easy to follow and had a user-friendly approach.

Most respondents considered that the handbook covered design management in sufficient detail. However, some design managers wanted more detail. One stated: "it covers design management well enough for other team members but not for design managers". The only respondents who did not consider that the handbook gave them a good understanding of design management were two practising design managers. One believing that after 30 years experience the knowledge required to manage the design process is very difficult to put into a book. However, apart from these criticisms typical comments were that it "helped in understanding design management processes" and provided an "in-depth explanation to help understand issues".

Very few barriers to implementation were identified, but different approaches to design management were considered necessary depending on the procurement route and that some tools were not appropriate in all cases. For example, consultant selections tools are not appropriate in the traditional procurement or novated design and build. This was addressed by highlighting the suitability of each tool for design and build, novated design and build and traditional procurement routes in the revised handbook.

A significant barrier identified during the review was the relatively low position of the design manager within the project team structure. As with much of the current industry approach, design management does not command significant authority within the power structure of a construction project (Heath *et al*, 1994). Focus remains on the construction activity because it accounts for the majority of the cost of a project, ignoring the potential impact of the design phase on the construction product (Newton, 1995). This illustrates the difficult task of implementing news ways of managing the design process if other project team members are unfamiliar with such methods. However, this also highlights the advantage of the approach taken by this research to educate all staff about design management and not simply design practitioners, an approach endorsed by Baldwin and Jarrett (2002). As well as helping to break down professional jealousies that can hinder team working (Baldwin and Jarrett, 2002) it can allow other professionals to understand the importance of design and its impact on procurement and construction phases.

handbook section		tools provided		training initiative improvement actions
2	The design process			Detailed model of design process activities Structured and explicit design management process
3	Stakeholders objectives, briefs and tasks	P01 P02 P03 P04	Brief document Concept design kick-off meeting Scheme design kick-off meeting Detailed design kick-off meeting	Tool to review / check the developed design will meet stakeholder requirements
4	Managers and structures			Detailed design manager job description
5	Selecting team members	P07 P08	Consultant benchmarking Consultant interviews	360 degree performance appraisals for all project parties supported by database of benchmarking data.
10	Design changes	P05	Design change workshop	Comprehensive design change management process

Table 3: Suggested modifications to the training initiative

Table 3 shows the changes that were requested, mostly for additional tools. These have been developed since the workshop and included in the revised handbook. In general, the handbook was well received with industrialists finding it user-friendly and written in a language that they understand. Also, as the tools were said to be easy to use and aligned with day-to-day activities then it would appear they do not impose any unwanted discipline. Most importantly, the majority of workshop attendees considered that the handbook gave them a better understanding of the design management process.

7.2 The Workshop

The responses to the training were very encouraging. In the questionnaire respondents were asked whether the context of each module within design management was made clear, the module provided understanding of issues surrounding topic and highlighted practical ways of dealing with issues. The responses are summarised in Tables 4, 5 and 6 respectively.

	minimum %	average %	maximum %
strongly disagree	0%	0%	0%
disagree	0%	1%	8%
neutral	0%	5%	25%
agree	33%	63%	83%
strongly agree	17%	31%	42%

Table 4: The context of the training module within design management was made clear

In seven of the ten training modules all respondents were clear about the context of the module within design management. This is probably because the modules were either introductions to design management (Design Management and Design Process) or they related to obvious activities within the process (Stakeholders' Objectives, Briefs And Tasks, Planning The Design Process, Ensuring Design Delivery, Managing Information Flow, Developing The Design). Some felt the Selecting Team Members module was not clear and that this is an issue normally dealt with by senior management rather than the design manager. Also, many projects in which the company are involved follow the traditional or novated design and build procurement route where team member selection happens before the company joins the project team. Therefore, it may not be clear to some how the selection of design team members is part of design management. However, in general, it is clear from the results in Table 5 that the attendees understood the training modules and how the ideas and tools presented apply to the design process.

	minimum %	average %	maximum %
strongly disagree	0%	0%	0%
disagree	0%	1%	8%
neutral	0%	4%	17%
agree	58%	73%	83%
strongly agree	8%	22%	42%

Table 5: Training module provided understanding of issues surrounding topic

All Respondents believed that seven of the modules (Design Management, Design Process, Stakeholders' Objectives, Briefs And Tasks, Planning The Design Process, Ensuring Design Delivery, Managing Information Flow, Developing The Design.) provided an understanding of issues surrounding the topic. Some suggested that Managers And Structures and Selecting Team Members needed more detail. This included additional explanation of organisational structures that support design management; a description of the support available to train design managers and an emphasis that the design manager must concentrate on being a manager of the design process and not get too involved in designing. Respondents also felt that the Selecting Team Members module needed further definition: the responsibility and parties involved in consultant selection should be clear and such practices only related to D&B type procurement routes. These issues have been addressed in the revised handbook and training modules.

It can be concluded that the training provides a good understanding of each design management topic as an average of 95% of respondents considered this to be the case.

	minimum %	average %	maximum %
strongly disagree	0%	0%	0%
disagree	0%	6%	17%
neutral	17%	29%	50%
agree	33%	60%	83%
strongly agree	0%	5%	17%

Table 6: Training module highlighted practical ways of dealing with issues

Five of the training modules (Stakeholders' Objectives, Briefs And Tasks, Ensuring Design Delivery, Selecting Team Members, Managing Information Flow and Developing The Design) were considered to highlight practical ways of dealing with issues. This would be expected, as their focus is the introduction of nineteen of the twenty-one tools.

However, the majority felt that the tools supporting the Managers and Structure module did not highlight practical ways of dealing with issues. Workshop attendees wanted to see the additions given in Table 3, which have subsequently been added to the revised handbook.

Overall, an average of 65 % of respondents considered that the workshop modules provided practical ways of dealing with issues. If we consider the modules that respondents did not rate highly, two provided an introduction to design management and therefore did not introduce any tools. Secondly, the Managers And Structure module required additional material. Finally, comments suggested that P05 Design Change Workshop introduced in the Design Changes module was insufficiently developed. With these exceptions an average of 74% considered that the modules highlighted practical ways of dealing with problems and the concerns raised in the workshop and questionnaires have now been addressed in a revised handbook and training material.

Workshop attendees commented that they liked the mix of learning activities (presentation, worked examples, discussion and problem solving) structured into the training modules, making them involved in the training process. However, several people said that they would have liked to see more worked examples to help improve their understanding of how to use the tools and their potential benefits.

Other than the above specific issues, there were no fundamental difficulties identified with the training modules and the material they delivered. We therefore conclude that the training modules should provide future attendees with an understanding of how each topic fits into the design management discipline, the issues surrounding design management and practical ways of managing the process.

8. CONCLUSIONS

This paper has reported on the development, content and deployment of a design management training initiative within a major UK civil and building design and construction company. This has led to the following conclusions:

1. The design management training initiative provides a sound understanding of the issues surrounding modern design management and practical ways of managing the process.

2. The initiative has the potential to change and improve design management performance within a design and construction organisation as it provides employees with a better understanding of what approaches, tools and practices that can help them improve the management of the design process.

3. Design management can be affected significantly by the actions of others, but the design manager is often unable to influence matters due to lack of authority.

4. Any changes to design management practices must involve educating all project parties that interface with the design manager.

5. The position of a design manager within the project team must be comparable to other senior managers to provide the authority which is necessary for the role.

6. Improving design management practice within a design and construction organisation is a long-term activity and must also overcome a range of barriers, not least the underlying company and construction industry culture.

9. ACKNOWLEDGEMENTS

The authors would wish to thank Skanska UK Building and the Engineering and Physical Sciences Research Council (EPSRC), which have provided the funding for this work through the Centre for Innovative Construction Engineering at Loughborough University.

10. REFERENCES

Austin, S., Baldwin, A., Hammond, J., Murray, M., Root, D., Thomson, D. and Thorpe, A., 2001, *Design Chains: A handbook for integrated collaborative design*, Thomas Telford, London.

Austin, S., Baldwin, A., Hammond, J. and Waskett, P., 1999, "Application of the Analytical Design Planning Technique in the Project Process" in *Proceedings of the Conference on Concurrent Engineering in Construction*, VTT, Finland.

Austin, S.A., Baldwin, A.N., Newton, A.J. 1996, "A data flow model to plan and manage the build design process", *Journal of Engineering Design*, Vol. 7, No. 1, pp 3-17.

Baldwin, J. and Jarrett, N., 2002, *Rethinking Construction - Accelerating Change: Compendium of responses to the consultation paper by the Strategic Forum for Construction*, Warwick Manufacturing Group, University of Warwick, UK.

Bibby, L., Austin, S., Bouchlaghem, N., 2002, "Defining an improvement plan to address design management practices: a case study of a UK construction company" *International Journal of IT in Architecture, Engineering and Construction* (*IT-AEC),* Accepted for publication in early 2003.

Business Round Table, 2002, *Teamwork2000 – an experiment in collaborative working*, Business Round Table, Kenley, Surrey, UK.

Egan, Sir J., 2002, *Accelerating Change: a report by the strategic forum for construction,* Rethinking Construction c/o Construction Industry Council. London, UK.

Egan, Sir J., 1998, *Rethinking Construction: the report of the construction task force*, Department of the Environment, Transport and the regions. London, UK.

Filson, A. and Lewis, A. 2000, "Cultural issues in implementing changes to new product development process in a small to medium sized enterprise (SME)", *Journal of Engineering Design*, Vol. 11, No. 2, pp 149-157.

Fellows, R. and Liu, A. 1997, *Research Methods for Construction*, Blackwell Science, Oxford.

Freire, J. and Alarcon, L.F. 2000, "Achieving a lean design process" in *Proceeding of the 8th International Group for Lean Construction Conference*, Brighton, England.

Frost, R.B. 1999, "Why does industry ignore design science", *Journal of Engineering Design*, Vol. 10, No. 4, pp 301-304.

Heath, T., Scott, D., Boyland, M. 1994, "A prototype computer based design management tool", *Construction Management and Economics*, Vol. 12, pp 543-549.

Kettley, P. 1995, "Is flatter better? Delayering the management hierarchy", *The Institute of Employment Studies, Report 290*.

Moore, D.R. and Dainty, A.R.J., 1999, "Work-group communication patterns in design and build project teams: an investigative framework", *Journal of Construction Procurement*, Vol 6, No1, pp 44-53.

Office of Government Commerce, 2002, www.ogc.gov.uk

Newton, A.J. 1995, "The improved planning and management of multi-disciplinary building design", *PhD thesis*, Department of Civil and Building Engineering, Loughborough University, Leicestershire.

Race, P. 2001, *2000 Tips for Lecturers*, Kogan Page, London.

Thomson, D.S. and Austin, S.A., 2001, "Construction Value Management Revisited: The designer's role" in *Proceedings of Cobra 2001 Conference*, Glasgow Caledonian University, Glasgow, UK, RICS Foundation.

APPENDIX D PAPER 4

Bibby, L., Austin, S and Bouchlaghem, D., 2003b, "The Impact of a Design Management Training Initiative on Project Performance", *To be Submitted for Publication.*

THE IMPACT OF A DESIGN MANAGEMENT TRAINING INITIATIVE ON PROJECT PERFORMANCE

L. Bibby, S. Austin and D. Bouchlaghem [1]

ABSTRACT

Over recent years there has been a significant drive away from traditional procurement routes with contractors finding themselves with an increasing responsibility for control of design - a process they have had little experience in managing. Yet this is an area of significant opportunity for those contractors who can adapt quickly and effectively to the changing construction market. However, many current processes are insufficient to manage today's demanding and fast moving projects.

The paper reflects on the deployment of a design management training initiative to improve performance in a major UK civil and building design and construction company. It investigates the impact of the training initiative, critical practices and a suite of 25 tools on design management performance across the company. It highlights benefits delivered by the initiative as well as the practices and tools crucial to successful design management. The paper also explores the range, significance and hierarchy of implementation barriers that affect the success of design management practices and reports on strategies that have been used on a case study project to overcome such barriers. The paper is likely to be of interest to those involved in design management and the development of tools and practices to help the industry improve design management performance.

Keywords: construction, design, management, industry practice, process, tools, training.

1. INTRODUCTION

Over recent years there has been a significant drive away from traditional procurement routes with contractors finding themselves with an increasing responsibility for control of design - a process they have had little experience in managing. They now have to adapt accordingly. The learning curve is steep, not least because many projects must now be delivered fast track while co-ordinating the increasingly complex fabric (Austin *et al*, 1996) and content of buildings without a platform of accepted good practice to manage the design process. This is major factor preventing the UK construction industry from delivering projects on time, to budget and to the specified quality.

As the target is to increase Design &Build projects to a 50% share of the UK construction market by 2008 (Egan *et al*, 2002) it is necessary to educate an increasing number of people in design management practices and tools to equip them to manage

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today's fast moving and demanding projects. However, many current design management tools are insufficiently developed for industry (Bibby, *et al*, 2003b). They are fragmented, insufficiently developed, poorly deployed and couched in abstract terms (Freire and Alarcon, 2000; Frost, 1999). Moreover, as they tend to be overly complex and force practitioners into unwanted discipline (Kanter, 2000) they are unlikely to gain wide adoption. Therefore, to improve design management in the industry current techniques must be modified to align them with the needs of the modern design manager to manage the construction design process.

Previous research (Bibby *et al*, 2003b) has developed a training initiative to improve design management within a major design and construction company with interests in PFI, Prime Contracting, D&B as well as traditional contracting. For the past three years, through a partnership with Loughborough University and the Engineering and Physical Sciences Research Council (EPSRC), it has been addressing its approach to design management to adapt to the changing UK construction market.

The initiative comprises a Design Management Handbook, Design Management Training, Team Support and Project Monitoring. The Design Management Handbook is the core of the training initiative. It provides guidance on critical aspects of design management practice and a suite of twenty-five tools. Training on practices and tools has been provided to approximately 600 employees across project teams throughout the company. Project teams have been supported in the implementation of the new practices and tools through Team Support to help embed new ways of working in company practice. Project Monitoring has helped establish the impact of the new practices on project performance to demonstrate that they are working and thus reinforce change.

The effectiveness of the training initiative on the company's design management performance has been explored through a combination of questionnaires, semi-structured interviews, maturity assessment and case study. This has established which practices and tools are being used, which ones are not as well as understanding the applicability and performance of each practice and tool. It has also identified the barriers to implementing new design management tools in industry as well as developing and testing strategies to overcome such barriers.

While the training initiative was undertaken to suit the needs of a major D&B contractor, its development was influenced by best practice within and outside the industry, as well as common barriers identified in literature (Bibby *et al*, 2002). Hence, lessons learned in this paper should be widely applicable to those in the industry involved in design management and the development of tools and practices to help the industry improve design management performance. Not least as specific research to quantify the impacts of success factors has been limited, particularly with respect to design performance (Kuprenas, 2003). Whilst the findings are based on a single organisation, the work carried out represents a significant step forward for the industry in developing strategies to deliver improvements to design management performance.

2. RESEARCH METHODOLOGY

The research in this paper sought to establish the impact of the design management training initiative on individual and project performance. The methodology comprised a structured questionnaire, design management maturity assessment, semi-structured interviews and case study investigation.

The structured questionnaire identified who out of 46 employees exposed to the training initiative as part of a pilot study had used the design management handbook practices and tools. This was to identify who was to be interviewed in more detail, why others did not use the handbook and their views on the awareness training. Interviewees comprised 15 Design Managers 5 Project Planners, 8 Quantity Surveyors, 5 Project Directors, 5 Project Managers, 3 Bid Managers, 2 Systems Managers, 1 Document Controller and 2 Procurement Managers spread over 14 projects. Good practice in preparing and conducting the questionnaire was used in this research (Race, 2001; Fellows and Liu, 1997).

The maturity assessment used a Design Management Maturity Model shown by Figure 1 and conceptually based on the Capability Maturity Model (Rosenstock, Johnston, & Anderson, 2000; Skulmoski, 2001) which has widespread acceptance as a standard for assessment of organisational maturity (Crawford, 2002). It is a two dimensional matrix with the horizontal and vertical axes representing the level of maturity (between 1 and 5) and the key areas of design management respectively. The nine key design management areas and their maturity levels were defined by a reference to previous work (Bibby *et al*, 2002; Bibby *et al*, 2003b) and a model developed to test maturity of design supply chains (Austin *et al*, 2001).

The assessment was carried out in three stages. The first and second stages were carried out immediately before and after all 46 respondents received awareness training. This was to establish the change in opinion on the company's design management performance caused by the training. The final assessment took place as part of the semi-structured interview exercise and aimed to capture the change in design management maturity delivered by the training initiative. As this final assessment was carried out with those that had used design management handbook practices and tools, only these results have been used to identify the impact of the training initiative on design management maturity within the company. While it would have been preferable to capture the opinion of all 46 respondents at the final assessment stage, the results are still considered valid as the exercise captured the change in opinion of individuals on the company's design management maturity over the period of the training initiative.

	Level 1 Haven't thought about it	Level 2 Thinking of doing something about it	Level 3 Beginning to do something about it	Level 4 Doing it as normal business	Level 5 Advanced practices developed
establishing and communicating design briefs	no process to establish and communicate project design briefs	inconsistent approach to establishing and communicating project design briefs	collaboratively ensure all stakeholders needs are articulated, captured and understood before phase begins	consistently establish and communicate work scope and delivery details for whole project	consistently establish and communicate work scope and delivery details for whole project and individual disciplines
design management roles and responsibilities	no consideration given to defining the roles and responsibilities of a design manager	ad-hoc approach to defining roles and responsibilities of a design manager	roles and responsibilities of a design manager defined	roles and responsibilities of design manager and the involvement of other parties in design management defined	all parties aware of their potential contribution to and involvement in design management
selecting team members	no selection process used to identify suitable design team members	inconsistent approach to assessing and selecting potential design team members	structured means to identify and assess consultant's skills	structured means to differentiate assessed skills of consultants to select a preferred consultant	performance data used to assess consultant skills and determine selection
integrated design planning	design is planned separately from the procurement and construction processes	major design activities planned with consideration of construction requirements	major design, procurement and construction activities linked and integrated	individual design activities of all disciplines integrated with each other and construction activities	resource allocation considered on integrated project programmes
ensuring design delivery	no effort to manage the distribution of design deliverables	document management recognised as a major task that must be improved	inconsistent management of the production and issue of design deliverables	consistent management of the production and issue of design deliverables	range of approaches to manage the production and issue of design deliverables to all parties
managing information flow	design information distributed to all parties without consideration of needs	recognised overload of information flow and need to improve practices	information distributed based on issuers perception of recipient needs	information needs of each party understood with parties able to access essential information	fully co-ordinated needs expressed: specific information requirements and why each is needed.
developing the design	design development undertaken in uncontrolled manner and designers working in isolation	inconsistent design development but designers collaborating on major issues	structured approach to design development and designers collaborating on most issues	structured approach to design development and designers collaborating where necessary	design team operating within fully integrated and collaborative design environment
value consideration in design process	no consideration of value in design development process	aware that can and should be considering value in the design process	inconsistent approach using value analysis techniques in the design process	phased set of value analysis activities structured into the design process	value generation process undertaken as an intrinsic part of the design development process
managing design changes	design changes implemented by instruction	inconsistent approach to the assessment of design change proposal	consider design changes proposals by identifying and assessing significant impacts	design proposals assessed consistently using structured process to identify and assess time, cost and quality impacts	ability to quickly and effectively explore potential design change options

Figure 1: Design Management Maturity Assessment Model

Semi-structured interviews captured the impact of the practices and tools presented by the training initiative on individual and project performance as well as the difficulties people had in applying the practices and tools. The views on the Design Management Handbook, the Awareness Training and a Design Management Intranet site set up as part of the training initiative were also sought. This approach avoided the potential for bias and difficulty in coding data associated with structured interviews and unstructured interviews respectively.

The 20 interviewees comprised 14 Design Managers, 1 Quantity Surveyor, 1 Project Director, 1 Project Manager, 1 Bid Manager, 1 Systems Manager and 1 Document

Controller spread over 8 projects. Good practice in preparing and conducting interviews was used in this research (Race, 2001; Fellows and Liu, 1997).

To understand the impacts of, and the barriers to using each of the design management practices and tools, interview results were coded and analysed in four steps:

> ***Step 1:*** impacts and barriers identified by interviewees against each practice and tool were categorised into 14 separate impacts (critical and supportive) and 23 separate barriers (selection, pre-application and application barriers) respectively. Critical impacts are primary project goals related to time, cost and quality, e.g. a design meeting all client requirements. Supportive impacts are precursors to achieving critical impacts; e.g. project team members are collaborating. Selection barriers will stop a user choosing to use a tool; e.g., a tool might not be appropriate for the procurement route being considered. Pre-application barriers dissuade users from applying a tool that in the belief that project circumstances would prevent it from being successful. E.g., a lack of agreed project design management processes could prevent a change control process being introduced as it may not be recognised or used by other project team members. Application barriers are those barriers that affect the successful operation of a tool in use. E.g., project parties not collaborating can have a significant affect on focusing development early in the process.
>
> ***Step 2:*** Equation 1 was used to establish the percentage (P_1) of respondents using each practice / tool that reported an impact. Equations 2, 3 and 4 were used to identify the percentage of respondents identifying selection, pre-application and application barrier at the choice, preparation and implementation stage of each practice and tool - P_2, P_3, and P_4 respectively. These four equations helped identify the relative significant each impact and barrier.
>
> ***Step 3:*** To highlight which impacts and barriers were most significant it was necessary to differentiate impacts identified by few from those identified by many. Equation 5 was developed and used to obtain a weighted score for each impact and barrier.
>
> ***Step 4:*** The weighted scores in each category (critical and supportive impacts, selection, pre-application and application barriers) were ranked and cumulative percentage graphs of the weighted scores prepared. This identified the impacts / barriers that represented 80% of the maximum cumulative weighting score in each category and thus which can be considered the most significant.

$$P_1 = \frac{\Sigma \text{ practice / tool had positive project impact}}{\Sigma \text{ used practice / tool}} \times 100 \qquad P_3 = \frac{\Sigma \text{ pre-application barrier reported against practice / tool}}{\Sigma \text{ not had opportunity to use practice / tool}} \times 100$$

$$P_2 = \frac{\Sigma \text{ selection barrier reported against practice / tool}}{\Sigma \text{ did not need to use practice / tool}} \times 100 \qquad P_4 = \frac{\Sigma \text{ application barrier reported against practice / tool}}{\Sigma \text{ used practice / tool}} \times 100$$

Equations 1, 2, 3 and 4: Equations for calculating P_1, P_2, P_3, and P_4

$$W = 10(0.05a + 0.25b + 0.5c + 0.75d)$$

W - weighted score for impact / barrier

a - number of times impact / barrier identified by at least 5% respondents

b - number of times impact / barrier identified by at least 25% respondents

c - number of times impact / barrier identified by at least 50% respondents

d - number of times impact / barrier identified by at least 75% respondents

Equation 5: Weighted Score for Design Management Impact or Barrier

The case study was undertaken to help understand at first hand issues and barriers to deployment of design management practices and tools. The project team was supported in implementing practices and tools. The views of the project team, client and designers were sought throughout the exercise to determine the appropriate tools, how they integrated with other project processes, whether any modifications or additions were required and to how to overcome selection, pre-application and application barriers.

3. DESIGN MANAGEMENT AWARENESS TRAINING

The awareness training (where practices and tools are presented) was well received as illustrated by Table 1. Many believed it helped to appreciate design management issues by expanding and clarifying their own ideas and covered all issues in a detailed and methodical way. Interviewees liked the open forum presentation style that allowed discussion of issues by all project team members. It also helped them work with the design management team and designers by explaining the benefits of practices / tools as well as explaining designers' needs and difficulties which has helped to break down professional jealousies that can hinder team working (Baldwin and Jarrett, 2002).

	It has helped me appreciate DM issues		It has helped me work with DM team and designers		It has improved my performance		It has improved project performance	
	total	%	total	%	total	%	total	%
strongly disagree	0	0%	0	0%	0	0%	0	0%
disagree	0	0%	1	2%	2	4%	2	4%
neutral	4	9%	7	15%	8	17%	23	50%
agree	33	72%	32	70%	31	67%	21	46%
strongly agree	9	20%	6	13%	5	11%	0	0%

Table 1: Comments on Design Management Awareness Training

Over three-quarters of interviewees consider that their personal performance was improved by attending the awareness training. Several said it helped understand the design process, its issues and potential bottlenecks in detail; showed how to prepare a good design programme and emphasised the need for the whole project team to respect the design freeze process. Almost half of interviewees said the awareness training positively affected project performance by getting the construction team to understand design management and the whole team to questions and improve design management and other project processes. Several suggested that design process improvements were difficult to identify as they were masked by the activities of other project members. For example, when a designer issued drawings early subsequent procurement and construction activities were not ready to use the drawings - resulting in lost improvements. Also, several interviewees noted that designers were reluctant to plan the design in detail and the client was not respecting the design freeze process. Such examples illustrates the effect of departmentalising in sub-optimising the design process in line with Womack and Jones' (1996) lean thinking and reinforces the findings of earlier work (Bibby *et al*, 2003a) that design management can be significantly affected by the actions of others in the "project system".

One unanticipated comment repeated by several interviewees was that the mere presence of the researcher within the company had a positive impact on design management performance. By being a persistent champion for design management it has raised the awareness of design management and acted as an impetus for change across the company. It may have also addressed a key problem of training noted by (Beer *et al*, 1993) that employees often become frustrated when their new skills go unused in an organisation where nothing else has changed – thus undermining commitment to change. However, as the presence of the researcher has maintained the momentum of the change programme this has helped to address such barriers.

Several conclusions can be drawn from these observations. The awareness training has been successful by getting the project team to understand design management, to work with design management / design teams and has improved their personal performances. Also, the presence of the researcher within the organisation has acted as an impetus for change. However, process improvements can be hidden by other project operations. Therefore, future projects should include the design team and client in awareness training, delivered at each project start up and involve the agreement of project design management processes. This helps ensure a consistent process (Kagioglou *et al*, 1998) and allows genuine involvement which is essential for introducing new ways of working (White, 1979). It is therefore a good strategy for addressing pre-application barriers. On the case study project all parties commented on and agreed design management processes, which has helped to embed the practices and tools in the project processes.

4. DESIGN MANAGEMENT HANDBOOK, PRACTICES AND TOOLS

4.1 Use of the Handbook

The overwhelming majority (14/15) of design managers did use the handbook with only one unable to do so because of lack of time and support resources to prepare tools for his project. Encouragingly 6 non-design managers also used the Design Management Handbook practices and tools. The remaining 26 interviewees did not use the practices and tools: 12 did not need to use it as part of their work and 14 did not have the opportunity to use the practices and tools. This was due to one of the following:

- the practice or tool being introduced too late for use in the project process;
- current processes not written to suit application of the tools; or
- that interviewees lacked the time or resources to put the tool into place.

However, some said they would use the Handbook in future if processes were mandatory, if all project operations were involved in defining project design management processes and if more project time was allowed to develop processes.

The first two barriers were addressed on the case study project by involving all project disciplines in the selection of design management processes and their definition in a mandatory Project Design Management Plan (PDMP). As a lack of time is a common design phase problem (Austin *et al*, 1996) it is unlikely that more will be available to develop processes. However, case study comments suggest that using a model PDMP will require less time to define processes.

The Handbook tools were taken by the company and included in its Integrated Management System (IMS) available through the company Intranet. Few interviewees used it as it did not provide anything in addition to the Handbook, there were some initial access problems and many considered the format made it difficult to navigate the IMS.

In conclusion, design managers are clearly using the Handbook and other project disciplines are also starting to adopt it. Case study experience has shown that the deployment of a PDMP can help overcome implementation barriers.

4.2 Handbook Content and Format

Table 2 shows interviewees comments on the Handbook. An overwhelming majority considered that the handbook had a clear and logical format, which was also easy to read and understand. Many also liked the standalone format of each section containing all guidance for that subject area and directed users to the associated tools. The majority believed that the handbook provided a good understanding of the subject and showed how to manage the design process by providing good practice that can be applied relatively easily and explaining how to overcome typical design management problems.

	Has a clear and logical format		Is easy to read and understand		Gives me a good understanding of subject		Shows how to manage the design	
	total	%	total	%	total	%	total	%
strongly disagree	0	0%	0	0%	0	0%	0	0%
disagree	0	0%	1	5%	1	5%	2	10%
neutral	1	5%	4	20%	5	25%	1	5%
agree	16	80%	11	55%	10	50%	15	75%
strongly agree	3	15%	4	20%	4	20%	2	10%

Table 2: Comments on the Design Management Handbook

Table 3 shows there were no problems were reported with the content and style of any practice or tool, therefore, the Handbook appear to be useful tool to diffuse design management practices and tools throughout the company.

4.3 Use of Design Management Practices and Tools

There is an interesting picture of use and success of design management practices and tools amongst interviewees, principally illustrated by Tables 3, 4 and 5. Table 3 shows the level of use of design management practices and tools amongst interviewees. The values shown are the percentages of interviewees that agreed with the statements in the table against each practice and tool. Table 4 shows the critical and supportive impacts that were provided by each practice and tool. The values shown are the percentages of the interviewees that had used a practice / tool that reported a positive impact delivered by the practice or tool. Table 5 illustrates selection, pre-application and application barriers that affected the performance of each design management practice and tool. For selection barriers the value represent the percentages of interviewees that did not need to use a practice / tool as part of their work that reported that a selection barrier caused them not to use it. For pre-application barriers the value represent the percentages of interviewees that did not have the opportunity to use a practice / tool that stated this was caused by a pre-application. For application barriers the value represents the percentages of interviewees that used a practice / tool stating that an application barrier affected the performance. Values in all tables recorded as 0% have been omitted for clarity. The cells in the tables have also been shaded according to the key shown by each table to further aid clarity.

Generally, interviewees have used the design management practices and tools with many reporting positive personal and project performance impacts. All practices, apart from Rigorous Team Selection provided between three and five critical project impacts. Therefore, they are crucial to effective design management. The following practices delivered significant levels of critical and supportive impacts and as such are the foundations of design management: capturing, clarifying and owning stakeholder requirements; progressive freezing of design details; be more specific with design scope of works; involve parties at the right time in the process; monitor all design deliverables; control issues of deliverables and information.

As few interviewees undertook Rigorous Team Selection or used associated tools P07 Consultant Benchmarking and P08 Consultant Interviews it is difficult to establish their importance to effective design management. This activity is typically the responsibility of the company's senior management. Comments suggested they did not carry out design team selections in the rigorous and structured manner suggested by the Handbook. However, many believed that it is an important design management task and that the company should do it more rigorously. From this, it would appear that senior management have not taken the opportunity to take the lead to apply new design management processes.

Table 4 shows the practices against which users reported a low instance of positive impacts. These practices are: allowing adequate design time, planning the design in detail and collaboratively, managing interfaces, investigating and controlling potential design changes and focusing development effort early in the process are practices. This appears to be the affect of a combination of barriers at pre-application and application stages. The pre-application stage barrier affecting all practices is the lack of leadership from senior management. However, during application there are four common barriers affecting the practices: lack of leadership from senior management, construction team ignoring design freeze / change control, client ignoring design freeze / change control and parties not collaborating.

Key

Shade	Range
Darkest	75-100
Dark	50-74
Light	25-49
White	0-24

		Yes					No					
		I have tried to implement the practice / tool	It had a positive effect on my performance	It had a positive effect on project performance	Barriers affected the success of the practice / tool	I modified the practice to suit my needs	Do not need to use it as part of work	Not had opportunity to try practice / tool as yet	Did not understand handbook / training content	Did not like handbook / training style	Practice / tool does not help to manage the design process	Practice / tool does not fit with the project's procurement route
design management practices												
Rigorous team selection based on range of criteria		15	15	15	75	5	75	10				
Capturing, clarifying and owning stakeholder requirements		80	80	60	35			20				
Understanding the process of design in detail		95	85	65	35			5				
Allow adequate design time		65	35	25	80			35				
Plan the design in detail and collaboratively		80	65	55	50			20				
Integrate design, procurement and construction activities		85	70	70	40			15				
Progressive freezing of design details		80	65	65	50			20				
Be more specific with design team scope of works		90	85	70	30			10				
Control issue of deliverables and information		90	80	65	45			10				
Manage interfaces		75	65	55	65			25				
Investigate and control potential design changes		65	55	40	75			35				
Focus development effort early in the process		80	55	55	75			20				
Involve parties at the right time in the process		80	80	80	30			20				
Monitor all design tasks and deliverables		80	75	80	25			20				
planning tools												
P01	brief document	80	80	70	15	25		20				
P02	concept design stage kick-off meeting	15	15	15	75	5	75	10				70
P03	tender design stage kick-off meeting	25	25	25	60	15		75				
P04	detailed design stage kick-off meeting	15	15	15	60	10	55	25				50
P05	design change workshop	35	30	30	60			65				
P06	master design programme	65	65	50	55		15	20				
P07	consultant benchmarking	5	5	5	90		85	10				
P08	consultant interviews	5	5	5	95		85	10				
P09	discipline design programme	65	65	65	30		10	25				
P10	job description	5	5		55		95				30	
co-ordination tools												
C01	information transfer schedule	85	85	75	15	35		15				
C02	work package control document	75	75	70	5	35		25				
C03	co-ordination meeting	95	90	80	20	30		5				
C04	design workshop	65	65	65	10	15		35				
C05	staged information delivery	40	40	35	10	5	5	55				
C06	fix information	40	40	30	30	15	5	55				
C07	interface schedule	40	40	30	30	15	5	55				
development tools												
D01	value analysis	45	45	45	50	5		55				
D02	brainstorming	65	65	60		10	15	20			10	
D03	decision matrix	5	5	5	55		60	35			60	
D04	task force meeting				40		50	50			40	
D05	design review document	30	30	30	10	20	15	55				
D06	design proposal document	30	30	30	30	20	15	55				

Table 3: Use of Design Management Practices and Tools

Key

- 75-100
- 50-74
- 25-49
- 0-24

	Used the practice / tool	Do not need to use it as part of work	Not had opportunity to try the practice / tool as yet	critical impacts: Design delivered on time/early	Design met all client requirements	Delivered co-ordinated design	Fewer late design changes	Cost certainty of design	supportive impacts: All parties clear of their responsibilities	Helps identify / solve potential difficulties	Monitors and controls progress	Helps assess impacts of potential decisions	Got project parties collaborating	Provides audit of decisions made	Identified design interdependencies	Better design programmes	Incorporates needs of all stakeholders
design management practices																	
Rigorous team selection based on range of criteria	15	75	10							65				35			
Capturing, clarifying and ownership of stakeholder requirements	80		20	50	55	5	25	30	30	5			5				
Understanding the process of design in detail	95		5	5		20	10			35			30		45		
Allow adequate design time	65		35	15	10	10		10		15					10	15	
Plan the design in detail and collaboratively	80		20	30		45			25	25		15	45		20	20	
Integrate design, procurement and construction activities	85		15	45		45	5		20	10		5	35		5	5	
Progressive freezing of design details	80		20	75		30	55	5					15				
Be more specific with design team scope of works	90		10	50	50		50		45	5	5		5				
Control issue of deliverables and information	90		10	60	40	5	10		55								
Manage interfaces	75		25	5		15	5		55				5		45		
Investigate and control potential design changes	65		35	25			30	10	15			60	10				
Focus development effort early in the process	80		20	55	15	5	5	40		5							
Involve parties at the right time in the process	80		20	90	50	40	55	30		65			40				
Monitor all design tasks and deliverables	80		20	50					45	45	70						
planning tools																	
P01 brief document	80		20	50	55		45	15	70				15				
P02 concept design stage kick-off meeting	15	75	10						100								
P03 tender design stage kick-off meeting	25		75						100								
P04 detailed design stage kick-off meeting	15	55	25						100								
P05 design change workshop	35		65				30	15				70	30				
P06 master design programme	65	15	20	40		30			30				40		55	25	
P07 consultant benchmarking	5	85	10									100		100			
P08 consultant interviews	5	85	10								100	100					
P09 discipline design programme	65	10	25	55		40			45	25	10		15		25	90	
P10 job description	5	95															
co-ordination tools																	
C01 information transfer schedule	85		15	60	5	25			60		55				10	10	
C02 work package control document	75		25	65	55	5	25	5	45		15		20	5			
C03 co-ordination meeting	95		5			75	5		35	10			10				
C04 design workshop	65		35	25		30	15	10		75			60				
C05 staged information delivery	40	5	55	75	15		50	15					15	15			
C06 fix information	40	5	55	50			50	15					15				
C07 interface schedule	40	5	55			25			65				15				
development tools																	
D01 value analysis	45		55	45	65			55		35							
D02 brainstorming	65	15	20	15	15				10	85			15				
D03 decision matrix	5	60	35											100			100
D04 task force meeting		50	50														
D05 design review document	30	15	55	50	100		15	35			15						
D06 design proposal document	30	15	55	85	65		35	35									
monitoring tools																	
M01 progress report	75		25	55		55			20	45	60						
M02 progress meeting	80		20	65		50			40	50	75						
cumulative weighted % of times impact identified against all practices and tools																	
weighted score				33	6	5	4	2	14	7	5	4	3	3	1	1	1
cumulative weighted percentage score				66	78	88	95	100	71	80	86	91	94	96	98	99	100

Table 4: Impacts Delivered by Design Management Practices and Tools

Key

Shading	Range
darkest	75-100
dark	50-74
light	25-49
none	0-24

	selection barriers			pre-application barriers								application barriers										
	Responsibility of other management function	Does not help manage the design process	Not suited to D&B procurement route	Lack of leadership from senior management	No agreed project design management process	Client ignoring design freeze / change control	Inflexible construction programme	Commercial decisions / lack of decisions affecting design	Construction team ignoring design freeze / change control	Inflexible client programme	Parties not collaborating	Lack of leadership from senior management	Construction team ignoring design freeze / change control	Client ignoring design freeze / change control	Parties not collaborating	No agreed project design management process	Inflexible construction programme	Insufficient design resources	Commercial decisions / lack of decisions affecting design	Insufficient design management resources	Designers lacking required skills	Inflexible client programme
design management practices																						
Rigorous team selection based on range of criteria	100			100																		
Capturing, clarifying and ownership of stakeholder requirements				25	25			25					5	15	20							
Understanding the process of design in detail												10			20		10	10	5		5	
Allow adequate design time				15		15	30			30		25	25	10	40		25	15	25	10		15
Plan the design in detail and collaboratively				50	25		25	25				20	5	5	30	5	5	15		5	5	
Integrate design, procurement and construction activities				35			35					20	10	5	10	10	5	10	5	5	10	
Progressive freezing of design details				25								25	40	40	5	15						
Be more specific with design team scope of works				50								10				15		5	10	5	5	
Control issue of deliverables and information				50								15		10	10	15		20		5		
Manage interfaces				40	60							15	15	5	35	15	5	5		5		
Investigate and control potential design changes				30	15	30			15		15	40	40	40	15	25		10				
Focus development effort early in the process				25	50	25			25			25	30	25	30	15	5	5	20	5		
Involve parties at the right time in the process				25	50								5		15				15			
Monitor all design tasks and deliverables				25	25							15						5	5		5	
planning tools																						
P01 brief document				25	75															5		
P02 concept design stage kick-off meeting			100																			
P03 tender design stage kick-off meeting				40	35						5	40				20						
P04 detailed design stage kick-off meeting	10		90	20	20											35						
P05 design change workshop				15	25	40						15	45	30								
P06 master design programme	100			25	25							10		15	10		25	15	10	10		
P07 consultant benchmarking	100			50	50																	
P08 consultant interviews	100			50	50																	
P09 discipline design programme				20	20							25	10		15		10	25				
P10 job description		60																				
co-ordination tools																						
C01 information transfer schedule												5			10			5				
C02 work package control document												5										
C03 co-ordination meeting												15	5		10					5		
C04 design workshop												10										
C05 staged information delivery							10															
C06 fix information	100			10	10							15	25	25								
C07 interface schedule					45	10			10			15	15	15								
development tools																						
D01 value analysis				10	55	10						20	10		10	45						
D02 brainstorming		65																				
D03 decision matrix		100																				
D04 task force meeting		80																				
D05 design review document					20																	
D06 design proposal document					45											15						
monitoring tools																						
M01 progress report					20											5						
M02 progress meeting					25																	
cumulative weighted % of times impact identified against all practices and tools																						
weighted score	11	4	2	7.7	7.7	1.1	1.0	0.6	0.4	0.3	0.1	2.6	2.3	1.9	1.8	1.4	0.9	0.9	0.7	0.5	0.3	0.1
cumulative weighted percentage score	63	88	100	41	82	87	93	96	98	99	100	20	37	51	65	75	82	89	94	98	100	100

Table 5:Barriers Experienced by Design Management Practices and Tools

P01 Brief document, P06 Master design programme, P09 Discipline design programme were effective planning tools, positively affecting the performance of over half interviewees and delivering critical and supportive project impacts. P06 could perhaps have been more successful but was affected at the pre-application stage by the lack of leadership and agreed design management processes to get project teams to prepare and buy into detailed design planning. The application of P03 Tender Kick-off Meeting and P05 Design Change Workshop had some success. However, use and impact was limited with the former provided a supportive impact and the latter three critical impacts. P03 was affected by the lack of leadership and agreed design management processes at pre-application and application stages. Practitioners were dissuaded from using P05 through a lack of agreed design management process framework in which to base the tool and the client issued changes by instruction, thus ignoring design freeze and change control.

Few interviewees used P02 and P04 concept and detailed design kick-off meeting. It appears that they do not fit in with the company's role within the D&B procurement route. The company is rarely involved early enough in a project to use P02. In Design and Build project interviewees noted no clear step between tender and detailed design thus P04 was unnecessary and P03 Tender design kick-off meeting was sufficient.

Many did not use P10 Job Description, D03 Decision Matrix and D04 Task Force Meeting saying they did not help to manage the design process. Interviewees could not see any real application for D03 and D04 the tools in their work. P10 was considered too structured for the varied and fluid role of the design manager. Several respondents stated the Design Management Handbook itself provided sufficient guidance while allowing them to use professional judgement to respond to the project needs.

All co-ordination tools delivered critical and supportive impacts - illustrating their importance to effective design management, the tools providing the most critical impacts were C05 Staged Information Delivery, C02 Work Package Control Document and C03 Co-ordination Meeting. This establishes them as crucial co-ordination tools. Barriers affected few tools, with only C06 Fix Information significantly affected by the construction team and client ignoring design freeze / change control during application. C05 Staged Information Delivery, C06 Fix Information and C07 Interface Schedule were used by less than half of interviewees, even though they were effective tools. The lack of agreed design management processes did not provide the framework in which to apply C07. No major barriers were reported for C05 and C06. The only explanation interviewees offered is that while they are useful tools, they are not likely to be used as much as say P06 Master Design Programme or B01 Brief Document.

Development tools that can be considered crucial because they provided critical impacts were D01 Value analysis, D02 Brainstorming, D05 and D06 Design review and proposal documents. They helped deliver the design on time, meet all client and budget requirements. However, less than a third of respondents used D05 Design review document and D06 Design proposal document. While no significant barriers were affected D05 interviewees suggested that while useful the tool is not one that would be used as much as P06 master design programme or P01 brief document. The only significant barrier affecting D06 was the lack of agreed project design management process to make the project team buy into its use. This barrier also affected the use of D01 value analysis at both pre-application and application stages.

The majority of interviewees used M01 and M02 monitoring tools. They help deliver the design on time and ensure it is co-ordinated – marking them as essential tools.

In conclusion, all design management practices apart from Rigorous Team Selection, planning tools - P01, P05, P06, P09, all co-ordination tools, development tools - D01, D02, D05, D06 and all monitoring tools provided critical impacts and therefore are critical to design management.

Adequate design time, planning the design in detail and collaboratively, managing interfaces, investigating and controlling potential design changes and focusing development effort early in the process were affected by one principal barrier at the pre-application stage and four barriers in application. P02 and P04 concept and detailed design kick-off meeting are not suited to D&B procurement route. P10 Job Description, D03 Decision Matrix, D04 Task Force Meeting do not help to manage the process. P05 Design change workshop, D01 Value Analysis, C07 Interface schedule are affected by the lack of agreed processes.

4.4 Critical Impacts Delivered

Figure 2 illustrates the most frequently identified critical impacts that the practices and tools have delivered. The 80% cumulative weighted score shows that a timely delivered design and a design meeting client requirements are the most frequently delivered critical impacts. By considering the cumulative impact reported by 75% or more of respondents then 80% of responses also ensure a co-ordinated design and fewer late design changes. Therefore, critical impacts delivered by the practices and tools are a timely delivered design, a design meeting client requirements, a co-ordinated design and fewer late design changes.

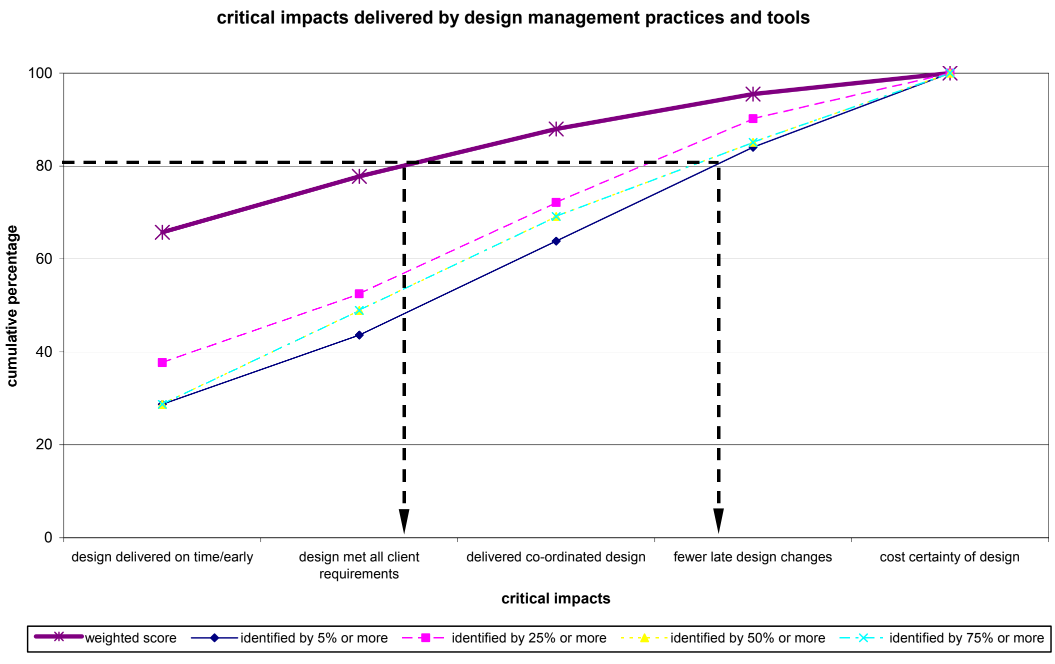

Figure 2: Critical impacts delivered by design management practices and tools

It is concerning that few practices and tools helped provide cost certainty of design, as it is such a crucial aspect of any project. However, this can be tempered by the fact that cost control is seen as a commercial team task rather than belonging to the design manager. This is supported by case study findings that the commercial team needed to modify commercial processes and their cost plan to align with the new design management processes.

5. BARRIERS TO IMPLEMETING PRACTICES AND TOOLS

5.1 Selection Barriers

Selection barriers are clearly significant when experienced as they prevent high proportions of users from using practices and tools in the first place. However, they do not occur in the frequencies of pre-application and application barriers, with only 11 significant instances (i.e. at least 25% percentage of respondents identifying barrier) of selection barrier affecting 11 practices and tools. Pre-application and application barriers had 43 and 21 significant instances where they affected the performance of 23 and 13 practices and tools respectively. Therefore, while selection barriers are very disruptive when encountered, they are not often a problem for design management practices and tools.

5.2 Pre-application and Application Barriers

Pre-application barriers accounting for 80% of the cumulative weighted score (Table 5) are a lack of leadership from senior management and no agreed design management processes. Therefore, these are the critical pre-application barriers preventing the majority of users trying to implement new design management processes.

Application barriers accounting for 80% of the cumulative weighted score (Table 5) are a lack of leadership from senior management, construction team and client ignoring design freeze / change control, parties not collaborating, no agreed design management processes and inflexible construction programme. Therefore, these are the critical application barriers affecting the operation of design management processes and mainly affect practices and planning tools.

When pre-application and application barriers are considered in combination (Figure 3), the key barriers accounting for 80% of the cumulative weighted score represent the critical barriers affecting the practices and tools throughout the design process. They are:

- a lack of leadership from senior management;
- no agreed project design management process;
- client ignoring design freeze / change control; and
- construction team ignoring design freeze / change control.

However, the only two barriers apparent at both pre-application and application stages were a lack of leadership from senior management and agreed design management process. Therefore, they are key barriers affecting the use of design management practices and tools throughout the design process.

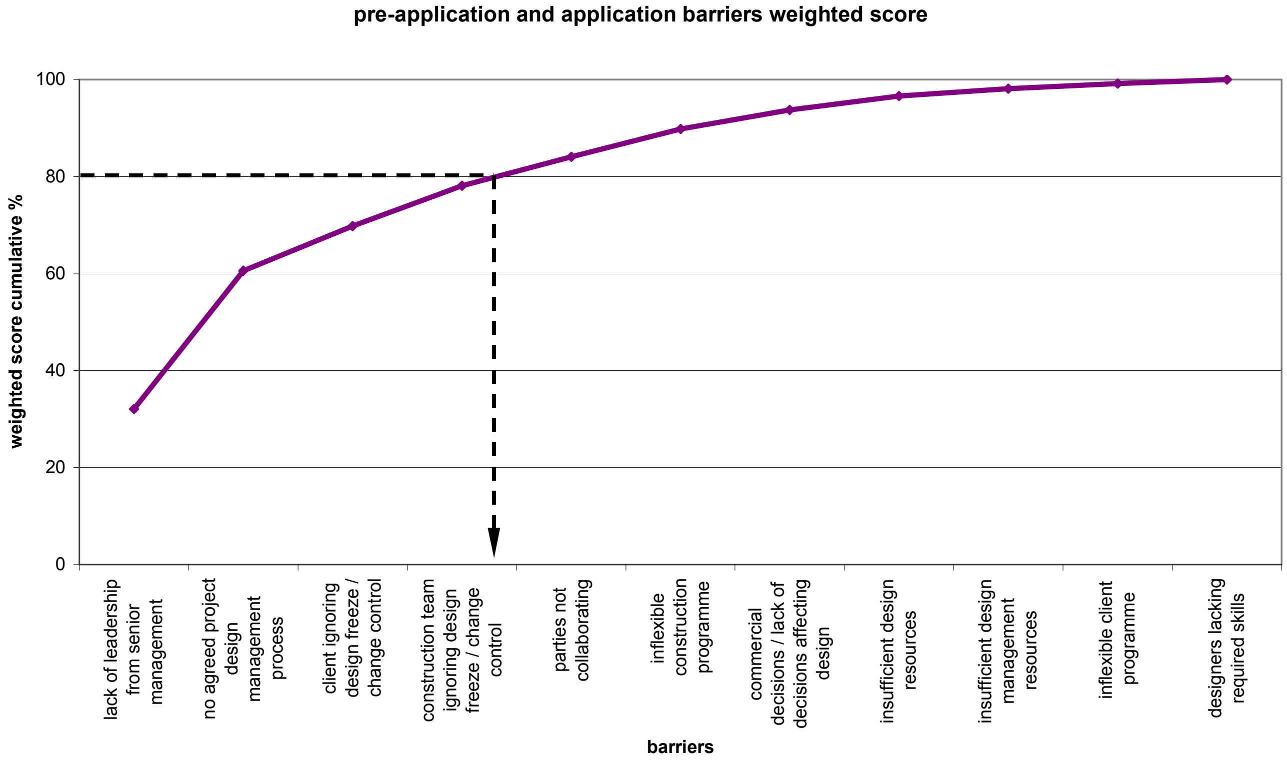

Figure 3: Pre-application and application barriers affecting design management practices and tools

5.3 Hierarchy of Pre-Application and Application Barriers

Figure 4 is a matrix where barriers in columns can cause barriers in the rows and illustrates the pre-application / application barrier hierarchy from interview comments. There are two clear groups of barriers that can be identified. The first group can be defined as primary barriers that can cause the other group - the secondary barriers.

The most influential primary barrier is the lack of leadership from senior management. It is potentially the pre-cursor to the other eleven barriers. For example, in the case of an inflexible client programme and the client ignoring the design freeze process a D&B contractor has the opportunity to illustrate to the client the project benefits of providing a more flexible programme and buying into the design freeze process. However, interview and case study experience suggest this opportunity could be taken more.

A lack of agreed design management processes, as the second most influential barrier has the potential to directly cause four other barriers and indirectly a further four barriers. The lack of leadership from senior management and a lack of agreed design management processes are both internally originating barriers, as are a further five out of the six primary barriers. In conclusion, it is clear that the company has significant influence over pre-application and application barriers and therefore has the capacity to reduce the effect of the barriers and improve the success of design management practices within projects.

Key

X	illustrates dependency
i	internal occuring barrier
e	external occuring barrier

		primary barriers						secondary barriers				
	internal or external	lack of leadership from senior management	no agreed project design management process	inflexible client programme	commercial decisions/lack of decisions affecting design	insufficient design management resources	inflexible construction programme	construction team ignoring design freeze/change control	client ignoring design freeze / change control	parties not collaborating	insufficient design resources	designers lacking required skills
internal or external		i	i	e	i	i	i	i	e	e	e	e
lack of leadership from senior management	i											
no agreed project design management process	i	X										
inflexible client programme	e	X										
commercial decisions / lack of decisions affecting design	i	X	X	X								
insufficient design management resources	i	X										
inflexible construction programme	i	X		X	X							
construction team ignoring design freeze / change control	i	X	X									
client ignoring design freeze / change control	e	X	X									
parties not collaborating	e	X	X			X	X					
insufficient design resources	e	X			X							
designers lacking required skills	e	X										

Figure 4: Matrix illustrating hierarchy of pre-application and application barriers

6. DESIGN MANAGEMENT HANDBOOK MODIFICATIONS

Figure 5 outlines the contents of the Design Management Handbook trialed throughout the company and modifications, additions and withdrawals based on interview comments and case study experiences. The tools P10 Job Description, D03 Decision Matrix and D04 Task Force Meeting will be removed from future versions of the Handbook as the majority of interview respondents did not use them, claiming they do not help to manage the design process.

Several modifications and additions were suggested. It was suggested to combine the designer's brief section of P01 Brief Document with C02 Work Package Document to streamline the briefing document issued to designers. This was undertaken for the case study project and to date has been welcomed by the project team.

The handbook size (256 pages) initially overwhelmed some interviewees believing they were expected to read it from cover to cover rather than as a reference tool to provide support where they need it. Therefore, the introductory section will be modified by explaining how best to use the Handbook. Other suggestions were to reinforce the need to rigorously review stakeholder requirements early in the project before contract close, as it is a key project risk area for the company, and provide more guidance on the level of design management resources required for a project.

A Project Design Management Plan was developed out of case study and interview findings which highlighted the need for a design management framework in which to define the practices and tools to be deployed on a project. It illustrates which, how and the format of the practices and tools to be deployed based on specific project processes and contractual requirements. It has been well received on the case study project by the team, designers and the client by providing clarity of how the design process will be executed and a framework for the design management practices and tools.

Also to be included are a suite of Design Process Performance Indicators. These are part of associated research at the company and will be added once complete.

Remaining additions were not design management activities as such, but rather activities carried out by other disciplines during the design process. Respondents recognised that commercial and procurement processes needed modification to align with the new design management processes. Also a model designers' contract was needed to limit delays in agreeing a contract that is acceptable to both parties.

In conclusion, the changes made were relatively small in number and most were minor modifications. The main changes were the removal of three tools and the provision of a PDMP to implement the Handbook practices and tools on projects. Significantly other project processes are now aligning with the new DM processes.

handbook section	topics cover and tools provided	modifications	additions	removals	reason
Introduction	origins of handbook, intended readership, handbook structure, contact information		Explain correct way to use handbook as a reference tool		Handbook size can be overwhelming and barrier to use
1 Design management	The need for and what is design management? Nature of the design process Why current design management goes wrong How can we better manage the design process?				
2 The design process	Nature of the process Involve parties at the right time Allow adequate design time Engender common design processes				
3 Stakeholders objectives, briefs and tasks	The need to, barriers to and incorporating stakeholder needs in the design				
	P01 Brief document P02 Concept design kick-off meeting P03 Scheme design kick-off meeting P04 Detailed design kick-off meeting	Combine design discipline part of brief document with work package document			Streamline designer briefing documentation
			Outline how to review stakeholder requirements, removing ambiguity in design brief docs		key risk area needing careful management
4 Managers and structures	The need for, barriers to, qualities of and training good design managers			P10 Job description	Does not help manage the design process
	P10 Job description				
5 Selecting team members	Importance of the team, necessary relationships and attitudes, skills and competencies		Model contract for designers		Need to align commercial with DM issues
	P07 Consultant benchmarking P08 Consultant interviews		Procurement schedule for subcontract design		Need to align procurement with DM issues
6 Planning the design process	The need for, barriers to and planning the design process		Project design management plan		Show how will use DM ideas and tools on specific project
	P06 Master design programme P09 Discipline design programme				
7 Ensuring design delivery	The need for, barriers to and effective design delivery	Combine design discipline part of brief document with work package document			Streamline designer briefing documentation
	C01 Information transfer schedule C02 Work package document C03 Co-ordination meeting M01 Progress report M02 Progress meeting		Design process performance indicators		Next phase of design management development
8 Managing information flow	The need for, barriers to and effective information flow management				
	C04 Design workshop C05 Staged information delivery C06 Fix information C07 Interface schedule				
9 Developing the design	The need for and barriers to effective design development Design Development during each project phase Focusing design development			D03 Decision matrix	Does not help manage the design process
	D01 Value analysis D02 Brainstorming D03 Decision matrix D04 Task force meeting D05 Design review document D06 Design proposal document			D04 Task force meeting	Does not help manage the design process
			Outline how to undertake cost control of design development		Need to align commercial with DM issues
			Cost plan		Need to align commercial with DM issues
10 Design changes	The effect of, barriers to, and managing design change proposals Identifying and				
	P05 Design change workshop				

Figure 5: Design Management Handbook Contents, Modifications, Additions and Withdrawals

7. DESIGN MANAGEMENT MATURITY ASSESSMENT

Figure 6 illustrates the three stages of the maturity assessment. The gap between the first and second assessments indicates the change in respondents' perception of the company's design management maturity caused by the awareness training. All maturity scores for design management areas reduced by an average of half a maturity level to 2.2 (18% reduction), to "Thinking of doing something about it" on the maturity scale (Figure 1). This highlighted inadequate practices, with the perception of the company's design management maturity was better than the reality. Significant reductions were associated with developing the design and managing design changes (both 0.8 drop) – two areas that are absolutely critical to successfully deliver a project. These and other maturity scores set the benchmark from which the company measured impacts of the training initiative.

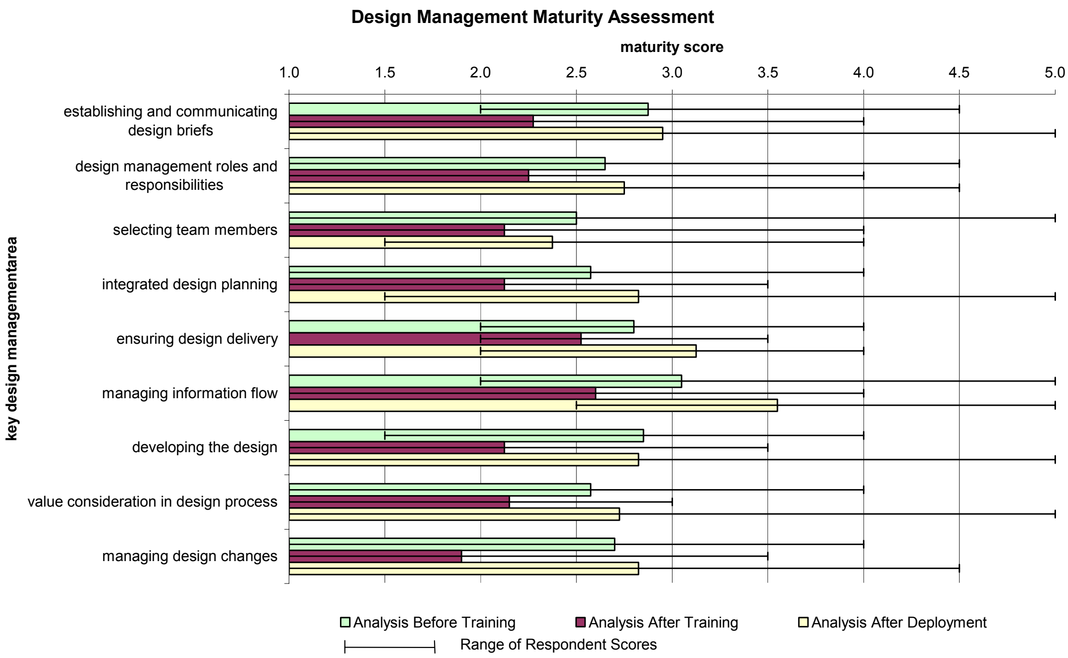

Figure 6: Design Management Maturity Assessment Results

The maturity assessment carried out after the training initiative had been deployed showed that respondents believe the company has improved all design management performance areas since the training started. The maturity score has increased by 29% from the second assessment to 2.9. This is almost a full level increase in maturity to "Beginning to do something about it". Notably there has been a 36% average increase to an average maturity score of 3.0 across Establishing and Communicating Design Briefs, Integrated Design Planning, Managing Information Flow, Developing the Design and Managing Design Changes – all fundamental activities to the successful design management. Other processes have also improved, albeit to a lesser degree. The least improved area was Selecting Team Members. This may be due to the fact that few respondents were involved in this exercise as it is the responsibility of senior management, yet few felt that this was being done rigorously.

Many interviewees considered the Design Management Maturity Model useful in helping understand current practices that are no longer working, where improvements are needed and how much they can improve – key factors in promoting change (Filson and Lewis, 2000). One interviewee offered "it shows clearly where we really need to focus our attention to improve performance". This suggests it is a useful tool in defining and helping to improve design management maturity.

In conclusion, according to the maturity assessment, the training initiative has raised awareness of the true design management performance across the company, and most importantly has delivered design management maturity improvements across the company. However, there is also significant scope for future development as the company reports a maturity score of 2.9 with the short term aim to ensure that all design management practices are being done as normal business (level 4).

8. CONCLUSIONS

This paper has reported on the impact of a design management training initiative within a major UK civil and building design and construction company. This has led to several conclusions.

The Handbook is being used and is useful for diffusing design management practices and tools and the training initiative has improved design management in practice.

The Design Management Maturity Model can help define and improve design management maturity.

30 out of the 39 practices and tools are critical to design management.

The critical impacts delivered most are a timely delivered design, a design meeting client requirements, a co-ordinated design and fewer late design changes, yet few practices and tools helped provide cost certainty of design.

Selection barriers can be very disruptive, yet do not occur often.

Lack of leadership from senior management and no agreed design management processes are the critical pre-application barriers.

Lack of leadership from senior management, construction team and client ignoring design freeze / change control, parties not collaborating, no agreed design management processes and inflexible construction are the critical application barriers.

Lack of leadership from senior management and the lack of agreed design management processes are the critical barriers throughout the design process.

A Design and Build Contractor has the capacity to improve the success of design management practices within projects by reducing the effect of the barriers.

Involving client and design team in the change process and using a Project Design Management Plan can help to implement design management practices and tools by overcoming key implementation barriers.

9. ACKNOWLEDGEMENTS

The authors would wish to thank Skanska Integrated Projects, Skanska UK Building and the Engineering and Physical Sciences Research Council (EPSRC), which have provided the funding for this work through the Centre for Innovative Construction Engineering at Loughborough University.

10. REFERENCES

Austin, S., Baldwin, A., Hammond, J., Murray, M., Root, D., Thomson, D. and Thorpe, A., 2001, *Design Chains: A handbook for integrated collaborative design*, Thomas Telford, London.

Austin, S.A., Baldwin, A.N., Newton, A.J. 1996, "A data flow model to plan and manage the build design process", *Journal of Engineering Design*, Vol. 7, No. 1, pp 3-17.

Baldwin, J. and Jarrett, N., 2002, *Rethinking Construction - Accelerating Change: Compendium of responses to the consultation paper by the Strategic Forum for Construction*, Warwick Manufacturing Group, University of Warwick, UK.

Beer, M., Eisenstat, R. A. and Spector, B., 1993, Why change programs don't produce change, *from Managing Change* (2nd Ed), Mabey C., and Mayon-White, B., (eds), Paul Chapman Publishing, London.

Crawford, J. K., 2002, *Project Management Maturity Model: Providing a proven path to project management excellence*, Marcel Dekker, New York.

Bibby, L., Bouchlaghem, D., and Austin, S., 2003a, "Design Management in Practice: Testing a Training Initiative to Deliver Tools and Learning", *Construction Innovation, Vol. 3, No. 4.*

Bibby, L., Austin, S., Bouchlaghem, N., 2003b, "Defining an improvement plan to address design management practices: a case study of a UK construction company" *International Journal of IT in Architecture, Engineering and Construction* (*IT-AEC),* Vol. 1, Issue 1, pp. 57-66.

Bibby, L., Bouchlaghem, N., Austin, S., 2002, "Delivering Learning and Tools to Improve Design Management in Practice", *Proceedings of CIB Conference on Measurement and Management of Architectural Value in Performance-Based Buildings*, Hong Kong, May 2002.

Egan, Sir J., 2002, *Accelerating Change: a report by the strategic forum for construction,* Rethinking Construction c/o Construction Industry Council, London, UK.

Fellows, R. and Liu, A. 1997, *Research Methods for Construction*, Blackwell Science, Oxford.

Filson, A. and Lewis, A. 2000, "Cultural issues in implementing changes to new product development process in a small to medium sized enterprise (SME)", *Journal of Engineering Design*, Vol. 11, No. 2, pp 149-157.

Freire, J. and Alarcon, L.F. 2000, "Achieving a lean design process" in *Proceeding of the 8th International Group for Lean Construction Conference*, Brighton, England.

Frost, R.B. 1999, "Why does industry ignore design science", *Journal of Engineering Design*, Vol. 10, No. 4, pp 301-304.

Kagioglou, M. Cooper, R., Aouad, G., Hinks, J., Sexton, M., Sheath, D., 1998, "*Generic design and construction process protocol final report*", The University of Salford, Salford, UK

Kanter, J., 2000, "Have we forgotten the fundamental IT enabler: ease of use", *Information Systems Management*, Summer, Pages 71- 77

Kuprenas, J.A., 2003, "Project Management Actions to Improve Design Phase Cost Performance", *Journal of Management in Engineering*, January, pp 25-32.

Race, P. 2001, *2000 Tips for Lecturers*, Kogan Page, London.

Rosenstock, C. , Johnston, R. & Anderson, L., 2000, "Maturity model implementation and use: A case study.", Proceedings of the 31st Annual Project Management Institute 2000 Seminars and Symposium.

Skulmoski, G., 2001, "Project maturity and competence interface, "Cost Engineering", Vol. 43, No 6, pp11-18.

White, K. 1979, "The Scanlon Plan: causes and correlates of success", Academy of Management Journal, Vol. 22, June, pp 292-312.

Womack, J. P. and Jones, D. T., 1996, *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*, Simon & Schuster, Sydney.

APPENDIX E PAPER 5

Bibby, L., Austin, S and Bouchlaghem, D., 2003c, "Developing Performance Indicators for the Construction Design Process", *To be Submitted for Publication.*

DEVELOPING AND TESTING PERFORMANCE INDICATORS FOR THE CONSTRUCTION DESIGN PROCESS

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ABSTRACT

Performance measurement has become popular in the construction industry over recent years. However, little effort has focused on the design process. At a time when the industry is striving to deliver better projects to clients and where the design process is crucial to such efforts, it is vital to establish effective ways of identifying where the design process can improve to help deliver projects faster, cheaper and with improved quality. As a starting point, this paper explores why the design process has been relatively neglected in the rush to benchmark the construction industry. It then establishes whether recent research projects cover all characteristics necessary to comprehensively monitor the design process, and presents a framework for the design of performance indicators. Finally, a suite of design process indicators capable of monitoring design process performance are introduced and put through a series of tests to establish whether they are suitable to monitor the design process performance. The paper is likely to be of interest to those involved in design management, performance indicators and the development of tools and practices to help the industry improve design management performance.

KEYWORDS: construction, design, management, performance indicators, process

1. INTRODUCTION

The concept of construction industry performance measurement has been in existence for several years (Lee, et al, 2000), gaining attention as a means of strengthening a company's ability to compete (Carpinetti and de Melo, 2002) through improving performance (CIRIA, 2000) and driving through changes to the way projects are managed. However, little of this effort has been directed towards the design process (Torbett *et al*, 2001), with no generic set of indicators to measure performance in design activities (Dent and Alwani-Starr, 2001) and as such they are poorly measured at both firm and industry level.

There is clear evidence to suggest why the construction design process has been relatively ignored in the rush to benchmark in the construction industry. Historically, there were clearer and more realisable benefits resulting from improving performance on site, both in terms of management and construction techniques and therefore much of industry research has been dedicated to this area (Austin *et al,* 1993). Edlin (1991) adds his support to this notion when he suggests that concentrating on improving construction efficiency can deliver the greatest financial savings. However, this is unlikely to be the only reason for the lack of design process performance measurement initiatives. Some lie in the nature of the design process itself. The iterative and poorly defined nature of the design process (Austin *et al* 1996) makes it difficult to determine progress. Also, as design solutions are not absolute answers, but rather are the product of negotiation, agreement, compromise and satisficing, any assessment of success must be relatively subjective. Therefore, developing performance indicators that can effectively and objectively account for the complex intrinsic nature of the design process is potentially very difficult.

Although the design process has been a relatively ignored area of performance measurement and its monitoring is very challenging; it is vital that the industry addresses this issue. The industry is being driven to change by clients expecting better performance (Gray and Hughes, 2001) making increasingly exacting demands in terms of time, cost and quality (Austin *et al*, 1994; Koskela 1999, Songer *et al* 2000, Strassman 1995, Tluazca and Daniels 1995). The design process has the opportunity to deliver. It is claimed to be the key project process (Morris *et al*, 1999; Cockshaw, 2001) that can provide functionality, quality, enhanced services, reduced whole life costs, construction time and defects as well as wider social and environmental benefits (Treasury Task Force, 2000; Prescott, 1999). Yet there are few examples where the process is a total success (Gray and Hughes, 2001). Generally, current practice is characterised by poor communication, lack of adequate documentation, deficient or missing input information, poor information management, unbalanced resource allocation, lack of co-ordination between disciplines and erratic decision making (Austin *et al*, 1994; Cornick, 1991; Hammond *et al*, 2000; Koskela, 1997; Lafford *et al*, 1998). Therefore, a way to improve design process performance is to measure it (Miles, 1998; CIRIA, 2000). This can be done by providing an understanding of practices that provide competitive advantage (Camp, 1995) through which will address the ever-rising customer requirements and expectations for improvements in the cost, timing and quality of construction output (Mohamed, 1998).

As part of a four-year research project to improve design management within a major UK civil and building engineering company, a suite of design process performance indicators have been developed. They have two key purposes: to monitor design process performance, and to determine the impact of new design management practices developed earlier in the programme.

While the research reported in this paper was undertaken to suit the needs of a major D&B contractor, its development was influenced by best practice within and outside the industry, as well as common barriers identified in literature (Bibby *et al*, 2002). Hence, lessons learned from work reported in this paper should be widely applicable to those in the industry involved in design management, performance measurement and the development of tools and practices to help the industry improve design management performance. Whilst the findings are based on the operations of a single organisation, the work carried out represents a significant step forward for the industry in developing strategies to deliver improvements to monitoring design process performance.

This paper reports on current performance measurement research projects within the construction industry as well as the development and testing of a suite of design process performance indicators. It also puts forward a framework for the design of performance indicators, initially prepared for the research in this paper, that provides guidance for the design of any type of performance indicator.

2. RESEARCH METHODOLOGY

The research presented in this paper sought to develop a suite of performance indicators capable of monitoring the performance of the construction design process.
The methodologies employed included a state of the art review, a review of company project management systems and structured interviews.

The state of the art review provided an up-to-date understanding of the construction design process, performance measurement practice within and outside the construction industry, identify recent initiatives within the industry and from this research gaps in performance measurement knowledge.

The review of the company's project management systems established the processes and tools that are used to manage the project design process and therefore the source of raw data. Specific tools that design process data was collected from were programmes, deliverable schedules, budget and actual cost plans, and RFI records. The review also highlighted the document control systems, project control systems and software that was available to help collate and compile the raw data into performance indicators. This review was carried out on three projects to identify and understand any variations in data collection and reporting across the company.

Structured interviews were used to establish what practitioners currently use to monitor design process performance, what they would like to use to monitor design process performance, and ultimately how useful they considered the suite of DPPIs for monitoring design process performance. To address the final question, practitioners were asked to rate each DPPI that had been prepared using sample project data. This was done on a 4 point scale (0 – not required; 1 – nice to have; 2 – important; 3 - essential) on its ability to monitoring design process performance. They were also asked if they had any open comments on each DPPI. This set of interviews was carried out with 10 design managers and 2 planning managers. Good practice in preparing and conducting the structured interviews was followed (Race, 2001; Fellows and Liu, 1997).

3. CURRENT DESIGN PROCESS MEASUREMENT PROJECTS

There have been several recent research projects and industry body initiatives to launch performance indicators within the construction industry. Most projects have focused on construction activities; however, some efforts are being made to develop some performance indicators of the design process. Comparison of eight projects (Table 1) against process characteristics suggested for construction project processes by Oakland and Sohal (1996) and supported by others (Love *et al*, 1999; Zairi, 1996; Eppinger, 2001; Hauser, 2001; and Alarcon, 1996) shows the extent that current design process measurement projects provide a comprehensive picture of design process performance.

		effectiveness	efficiency	productivity	quality	impact
		reflects whether processes are achieving the desired results	reflects wether process is performing efficiently	concerned with relating the process outputs to its inputs	concerned with customer requirements and quality	concerned with rework and material waste
1	Friere and Alarcon (2002)				no. of errors on design deliverables	no. of design changes
2	Design Quality Indicators (Construction Industry Council, 2002)				assessment of design quality at each project stage	
3	Consultant KPIs (CIRIA, 2003)	understanding client needs, design cost and time estimate, risk management	design process integration of design with supply chain, re-use of experience, use of innovative		client / user satisfaction	design change cost and time impact
4	Construction Industry Institute / European Construction Institute Benchmarking Initiative (2002)	team building	pro-project planning use of IT in design		constructability	project change management
5	PDRI (Construction Industry Institute, 1999)	completeness of project definition, basis of design and execution approach				
6	Last Planner / DePlan (Hammond et al, 2002)	percentage planned completion of design tasks				
7	CALIBRE2000 (BRE, 2000)	process mapping to eliminate waste	process mapping to eliminate waste	process mapping to eliminate waste		
8	Torbett et al (2001)	understanding client needs, profitability of design, integrating design into aims	internal / external design processes, efficiency of design, learning & innovation		satisfying client needs	

Table 1: Current Design Process Benchmarking Projects

From Table 1 it is clear that no project considers process performance across the full range of design process characteristics. It seems that the research projects focus predominantly on either design quality and impact or effectiveness and efficiency indicators. Very few projects address the productivity of the design process. The measurement methodologies for projects 2, 3, 4, 5, 7 and 8 (Table 1) require users to undertake an exercise (in addition to their normal work) to provide performance indicator results. Frost (1999) suggests that new tools proposed for adoption by industry should avoid this approach. New tools should relieve practitioners of boring or routine tasks rather than impose additional activities. The evident gaps in current performance indicator projects and potential implementation barriers suggested an opportunity for a suite of user-friendly and pragmatic performance indicators capable of representing the full range of Oakland and Sohal's (1996) process characteristics.

4. DEVELOPING DESIGN PROCESS PERFORMANCE INDICATORS

Developing a suite of design process performance indicators to be deployed in practice that provide a comprehensive picture of process performance must consider several factors. They must be designed to avoid the various difficulties of performance management, they must cover the range of Oakland and Sohal's (1996) process characteristics and ultimately practitioners must be willing to implement them in practice.

Avoiding the Pitfalls of Performance Indicator Development

As noted above performance measurement has many potential pitfalls if indicators are poorly designed or the surrounding process is incomplete. Generally, poorly designed indicators are poorly integrated with each other (Lynch and Cross, 1991) and lack a strategic focus. They can encourage short-termism, conservative non-risk taking behaviour, manipulation of statistics and inhibit continuous improvement (Neely, 1998; Womack and Jones, 1996). Therefore, intelligent design is necessary to ensure that a performance indicator avoids these problems.

A framework initially outlined by Neely *et al* (1997) has been modified by considering guidance from several authors. The framework is set out to address four key issues for performance indicator design:

- What it aims to achieve (Title, Purpose and Related Business Objective);
- What it will measure (Formula, Target and Comparison Partner);
- How will information be collected and presented (Data Source, Collection Frequency, Collector and Presentation); and
- What action will be taken (Responsibility and Action).

Table 2 is an example of the Modified Performance Indicator Framework.

section	considerations	example
title	Be clear, explain what measure is and why it is important (Globerson,1985; Fortuin, 1988). It should be self-explanatory and not include functionally specific jargon (Neely et al, 1997). Base on quantities that can be influenced, or controlled, by the user alone or in co-operation with others (Globerson, 1985; Fortuin, 1988). Measure must be able to have impact on key activities and be significant for success or failure (Sink, 1985). If the measure is for day-to-day control of processes then used non-financial measures. Indicators should be at the work team level (Walsh, 2000)	% of planned deliverables issued
formula	Formula must encourage desired types of behaviour and discourage dysfunctional behaviour. Make explicit any potential dysfunctional behaviour along with any mitigation measures (Neely et al, 1997). Systems thinking is a useful tool at this stage (Lantelme and Formoso, 2000). Base calculation on ratios rather than absolute numbers to aid comparison between benchmarking partners (Globerson, 1985).	% of planned deliverables issued by each party each week.
purpose	The rationale underlying the measure must be specified (Fortuin, 1988). It is necessary for users to understand relevance of a measure if it is to be used effectively (Cox and Thompson, 1998).	check deliverables issued when required
related business objective	Identify the business objectives and associated client requirements to which the performance indicator relates (Globerson, 1985; Fortuin, 1988; Maskell, 1991). Should focus on meeting client requirements and not internal requirements (Hopwood, 1984).	deliver projects on time
focus of measurement	There are four principal strategies. Performance Benchmarking compares performance measures, Process Benchmarking compares operations, work practices and business processes. Product Benchmarking compares products and/or services. Strategic Benchmarking compares organisational structures, management practices and business strategies (Carpinetti, L. C.R. and de Melo, A. M., 2002).	deliverable issue process
target	Indicator should have an explicit target: level of performance required and a timescale for achieving it (Globerson, 1985; Fortuin, 1988). To assess whether performance is improving rapidly enough. A specific, stretching, but achievable target is necessary (Globerson, 1985). Arbitrarily set targets can evoke frustration amongst those who have to achieve them, especially when insufficient resources are available. Targets should also be set at the work team level (Walsh, 2000). The primary objective of performance indicators is to understand those practices that will provide a competitive advantage; target setting is secondary (Camp, 1995).	planned deliverables issues
comparison partner	"Partners" are based on the four main types of benchmarking. Internal Benchmarking compares performance of units or departments within one organisation. Competitive Benchmarking compares products, services or business process performance with direct competitor. Functional Benchmarking compares technology and/or processes organisations in same industry with best practice. Generic Benchmarking compares processes against best process operators irrespective of industry. (Carpinetti, L. C.R. and de Melo, A. M., 2002, Camp, 1989, Khurrum and Faizul Huq, 1999).	Planned performance and other company projects
data source	The source of the raw data should be specified (Globerson, 1985). A consistent source of data is vital if performance is to be compared over time (Fortuin,1988).	deliverable issue schedule.
collection frequency	The frequency with which performance should be recorded and reported is a function of the importance of the measure and the volume of data available. The aim should be to provide timely and accurate feedback (Globerson, 1985; Fortuin, 1988). Data that is likely to change rapidly or reports a process needing close control requires frequent collection and reporting (Maskell, 1991). Automate process of data collection, processing and dissemination as much as possible (Globerson, 1985).	once a week
collector	The person who has the responsibility of collecting and reporting the data should be identified (Neely et al, 1997).	document controller
responsibility	The person who is to act on the data should be identified (Neely et al, 1997).	design manager
action	The management loop must be closed (Globerson, 1985). If cannot detail the action then define general management process to follow. This should be a formal step to properly evaluate results and develop new plans. This is particularly important if action is to be taken by a team as the measures must be reviewed (Bourne et al, 2000) and any action agreed by those who have responsibility for the performance being measured.	discuss late delivery with provider / recipient and agree corrective plan
presentation	To have visual impact it should be in a simple, consistent format based on trends and not snapshots (Fortuin, 1998; Crawford and Cox, 1990). Graphical format allow deviations from planned performance to be identified at a glance. Results should be publicised as widely as possible to engender an improvement-based culture. Keep cycle time between collection and presentation as short as possible to ensure information provided is relevant to those that need to act on it (Lantelme and Formoso, 2000).	in tabular and graphical format. Weekly and cumulative values to be shown

Table 2: Example Performance Indicator Framework

Motivating Practitioners to use Performance Indicators
To ensure that practitioners are prepared to implement each Design Process Performance Indicator (DPPI) it is necessary to establish the aspects of the process that they need to monitor and address any barrier that could restrict or prevent implementation of DPPIs in practice.

The range of project features identified by practitioners to be monitored can be summarised as: deliverable production, iterations required to complete deliverable, deliverable completeness, control of RFI (requests for information), resource use, cost of designed facility, approval delays, design change impacts. Words of warning were also offered: DPPIs should be simple, clear and understandable to all project parties – a point supported by Brunso and Siddiqi (2003).

In the construction industry process monitoring data is difficult to obtain (Cox and Morris, 1999) which typically requires practitioners to undertake data collection to prepare indicators. Imposing such unwanted procedures on practitioners in addition to their normal tasks is unlikely to get the tools adopted (Kanter, 2000). This was addressed by using data automatically collected as part of the design process as suggested by Globerson (1985). However, to avoid using data merely on the basis that it was readily quantifiable (Hinton *et al*, 2000) and ensure that it was appropriate for indicating design process performance, the data (and sources) relating to design process inputs and outputs was used. The results of this exercise are summarised in Table 3.

process input	**process output**	**data source**
staff resources		planned and actual master and discipline programmes, project cost plan
	design deliverables	planned and actual master and discipline programmes, deliverable issue schedule
	project cost information	project cost plans
	requests for information (RFIs)	RFI report on document management system

Table 3: Key Design Process Inputs and Outputs

The consideration of key process inputs and outputs allied to the modified Performance Indicator Framework, Oakland and Sohal's (1996) process characteristics and practitioners requirements produced a suite of practical and user-friendly DPPIs to comprehensively represent design process performance. Table 4 shows each DPPI and its associated purpose.

effectiveness	efficiency	productivity	quality	impact
% of planned deliverables issued	**average deliverable issue delay**	**% planned deliverable issued / % planned manhour costs**	**RFIs issued / deliverable issued**	**% project overrun due to design rework**
ensure required deliverables are being issued	*ensure deliverables issued in timely manner*	*identifies if resources used are producing corrrect level of resources*	*highlight if deliverables meet recipient's requirements*	*minimise delays due to design changes*
% of planned deliverables issued on time	**average RFI closing delay**		**average no. of revisions per deliverable**	**% project overspend due to design rework**
ensure required deliverables are being issued on time	*ensure RFIs responded to in timely manner*		*check design is being developed competently*	*minimise costs of design changes*
% of RFIs closed on time	**% of planned manhour costs**		**% content completion of issued deliverables**	
ensure RFI's closed when required	*ensure correct level of resources employed to meet commitments*		*highlight if deliverables meet recipient's requirements*	
% of planned deliverables approved for construction	**average comment issuing delay**			
ensure deliverables approved when required	*ensure documents not delayed unnecessarily by approver*			
	average delay in achieving approval			
	ensure deliverable comments issued in timely manner			

Table 4: Design Process Performance Indicators

5. TESTING NEW DESIGN PERFORMANCE INDICATORS

The testing of the DPPIs was undertaken to identify any barriers in data collection and transformation of the raw data into performance indicators as well as establish practitioners' views of the DPPIs. These are considered in turn.

Design Process Performance Indicator Data Collection

Three significant difficulties were encountered during the data collection for the DPPIs. They are summarised in Table 5. Across all three projects RFI schedules were incomplete (compared to paper records) with a significant proportion of missing and incomplete RFI records. This affected the validity of the RFI associated DPPIs. However, this has since been addressed for two of the projects (which are still ongoing) through the provision of a project extranet where RFIs are wholly managed electronically.

The receipt of deliverable comments was only recorded on paper versions of document receipt forms for all three projects and not in any easy to access electronic format. This precluded preparation of the DPPI: average comment issuing delay, as it would take significant effort to transfer the data to an electronic format. Again, for two ongoing projects the provision of an extranet has since resolved this issue.

It was difficult to establish the programme impact of design changes on any of the projects for DPPI: % project overrun due to design rework. Revised programmes were available but design change induced modifications were obscured in other programme modifications. Agreed additional designer manhours due to changes were available, but only in paper format and did not identify subsequent design change impacts on other design, procurement or construction activities and therefore could not be relied upon. This has since been addressed for the two ongoing projects as the design change control process as part of new design management processes (as noted in introduction) requires a formal analysis of all process impacts of a proposed design change before approval.

Therefore, as long as the deliverable comments and RFIs are managed electronically and design change control processes make explicit all process impacts of a change there appears to be no data collection problems for the DPPIs. Furthermore, this has unexpectedly identified that where project extranets handle design process data electronically this provides a useful source of raw data for process monitoring.

Transforming Data into Design Process Performance Indicators

Two barriers were identified during the transformation of raw data into DPPIs, these are summarised by Table 5. Firstly, the data sources used for the DPPIs were fragmented (e.g. deliverable schedules, project programmes, RFI schedules and cost plans) with no central project data source from which to compile a comprehensive DPPI report. However, as the majority of the data sources were spreadsheets (with only the RFI schedule needing to be exported to spreadsheet format) it was possible to transform each raw data set using some simple calculations added to its spreadsheet worksheet. The transformed data was then linked to a DPPI results spreadsheet where the results are presented. Therefore, when any raw data used for the DPPIs are modified, the DPPI results are automatically updated. Table 6 shows an example DPPI output and the transformation process is illustrated by Figure 1. This process ensured that DPPIs could be reported in a simple and easy to understand format as practitioners required, with the automatic conversion of data to DPPI avoiding any additional work for practitioners, as recommended by Kanter (2000) to help improve adoption of DPPI in practice.

The second barrier identified during the DPPI preparation was the lack of a standard protocol for the format of deliverable schedules. The format was different for each of the three projects and thus affected the production of deliverable related DPPIs. However, it was a relatively minor barrier and required the transformation calculations to be slightly modified rather than standardised for each project. Therefore, to ease implementation of the DPPIs and thus limit the need for user modifications it would be useful to standardise the deliverable schedule format. However, as the purpose of this work was to identify and address data collection and transformation barriers for DPPIs the actual tool to undertake this task requires further investigation. Therefore, future work will focus on developing more robust processes for automatic data capture.

		DPPI	purpose of DPPI	data collection difficulties	data transformation difficulties	benefits	barriers	average interviewee applicability score
effectiveness indicators	1	% of planned deliverables issued	ensure required deliverables are being issued		no standard protocol for decided what should be reported and how	easy to highlight delays and future required performance		3
	2	% of planned deliverables issued on time	ensure required deliverables are being issued on time		no standard protocol for decided what should be reported and how	easy to highlight delays and future required performance		2.6
	3	% of RFIs closed on time	ensure RFI's closed when required	not all RFIs issued reported in document management system		reinforces importance of hitting required issue dates	not a key issue - unlikely to promote required behaviour	1.4
	4	% of planned deliverables approved for construction	ensure deliverables approved when required		no standard protocol for decided what should be reported and how	puts focus on a key project goal		3
efficiency indicators	5	average deliverable issue delay	ensure deliverables issued in timely manner		no standard protocol for decided what should be reported and how	reinforces importance of hitting required issue dates		2.4
	6	average RFI closing delay	ensure RFIs responded to in timely manner	not all RFIs issued reported in document management system		reinforces importance of hitting required issue dates	not a key issue - unlikely to promote required behaviour	1
	7	% of planned manhour costs	ensure correct level of resources employed to meet commitments			indicates whether resource level sufficient to meet commitments		2.5
	8	average comment issuing delay	ensure documents not delayed unnecessarily by approver	no single doc reports constituent data required for DPPI	no standard protocol for decided what should be reported and how	important to show approvers commitment to the process		2.5
	9	average delay in achieving approval	ensure deliverable comments issued in timely manner		no standard protocol for decided what should be reported and how	puts focus on a key project goal		2.5
prodtvty indicator	10	% planned deliverable issued / % planned manhour costs	identifies if resources used are producing corrrect level of resources		no standard protocol for decided what should be reported and how	clearly shows productivity and cost effectivenes		2.9
quality indicators	11	RFIs issued / deliverable issued	highlight if deliverables meet recipient's requirements	not all RFIs issued reported in document management system			not a key issue - unlikely to promote required behaviour	0.6
	12	average no. of revisions per deliverable	check design is being developed competently		no standard protocol for decided what should be reported and how		will not control no. of deliverable re-issue	1
	13	% content completion of issued deliverables	highlight if deliverables meet recipient's requirements		no standard protocol for decided what should be reported and how	shows if deliverables need improving to meet requirements	deliverable completeness not always monitored	2.1
impact indicators	14	% project overrun due to design rework	minimise delays due to design changes	no revised programme produced to identify change impact		might stop changes being made if impact being measured	difficult to isolate impact of change	2.4
	15	% project overspend due to design rework	minimise costs of design changes			might stop changes being made if impact being measured		2.3

Table 5: Design Process Performance Indicator Test Results

			target	actual
effectiveness	1	% of planned deliverables issued	100%	16%
	2	% of planned deliverables issued on time	100%	7%
	3	% of RFIs closed on time	100%	49%
	4	% of planned deliverables approved for construction	100%	6%
efficiency	5	average deliverable issue delay	0 weeks	7.29 weeks
	6	average RFI closing delay	0 weeks	1.4 weeks
	7	% of planned manhour costs	100%	103%
	8	average comment issuing delay	0 weeks	n/a weeks
	9	average delay in achieving approval	0 weeks	8 weeks
productivity	10	% planned deliverable issued / % planned manhour costs	>100%	16%
quality	11	RFIs issued / deliverable issued	minimise	2.12
	12	average no. of revisions per deliverable	minimise	2.20
	13	% content completion of issued deliverables	100%	57%
impact	14	% project overrun due to design rework	0%	n/a
	15	% project overspend due to design rework	0%	3%

Table 6: Example Design Process Performance Indicators Results

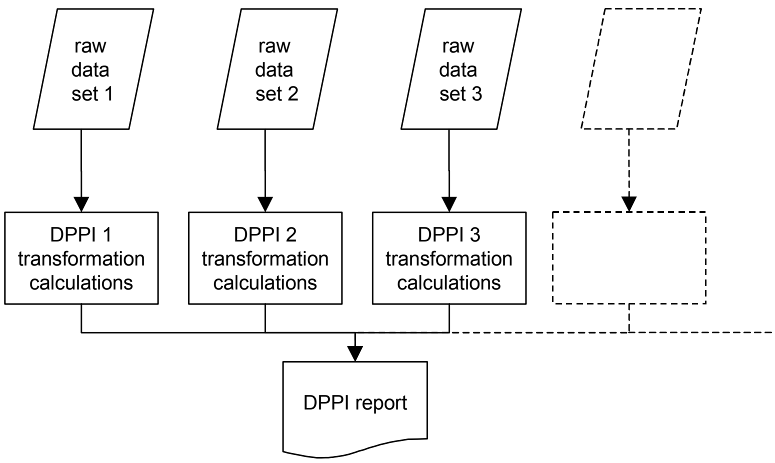

Figure 1: Raw Data to DPPI Transformation Process

While some of the targets and actual results for the DPPIs shown on Table 6 differ significantly suggesting the project on which this data was based is performing poorly there are no boundaries defining good or poor performance. While DPPI targets are intrinsically based on the planned process performance through the formulae that are used, merely having targets of 100% of planned issues and 0 weeks delay may not be appropriate. Like most systems the design process does not operate at maximum efficiency all the time and arbitrarily set targets can evoke frustration amongst those who have to achieve them, especially when insufficient resources are available (Walsh, 2000). Therefore, each DPPI requires a specific target that is stretching but achievable

(Globerson, 1985). However, there is no indication of the appropriate target level and this may even vary due to factors such as a project's scale, complexity and timescale. For example, for projects where planned performance is easy to achieve or critical then DPPI targets should be high. Therefore, future work will focus on establishing an appropriate set of DPPI targets dependent on project conditions.

While Globerson (1985) suggests that performance indicators should be based on ratios rather than absolute values wherever possible it was considered appropriate for DPPIs reporting delays to be expressed in weeks to present them in an accessible format to practitioners. This was done to improve adoption potential of the DPPIs amongst practitioners by illustrating the practical uses of DPPIs to support them in managing the design process. For the same reason it was also considered appropriate to present the deliverable production DPPIs (% of planned deliverable issue, % planned deliverable issue on time, and % planned deliverable issue / % planned manhour costs) in graphical format as numerical format for the same reason. The DPPIs: % of planned deliverable issue and % planned deliverable issue on time are shown in graphical format as planned and actual deliverable issue profiles instead of a percentage score of the actual to planned deliverables issued, this is shown by Figure 2. It was important to illustrate deliverable issuing trends, to help practitioners identify where management intervention might be required (e.g. increase deliverable production rate) and to enable forecasting activities to take place for deliverables and resourcing issues.

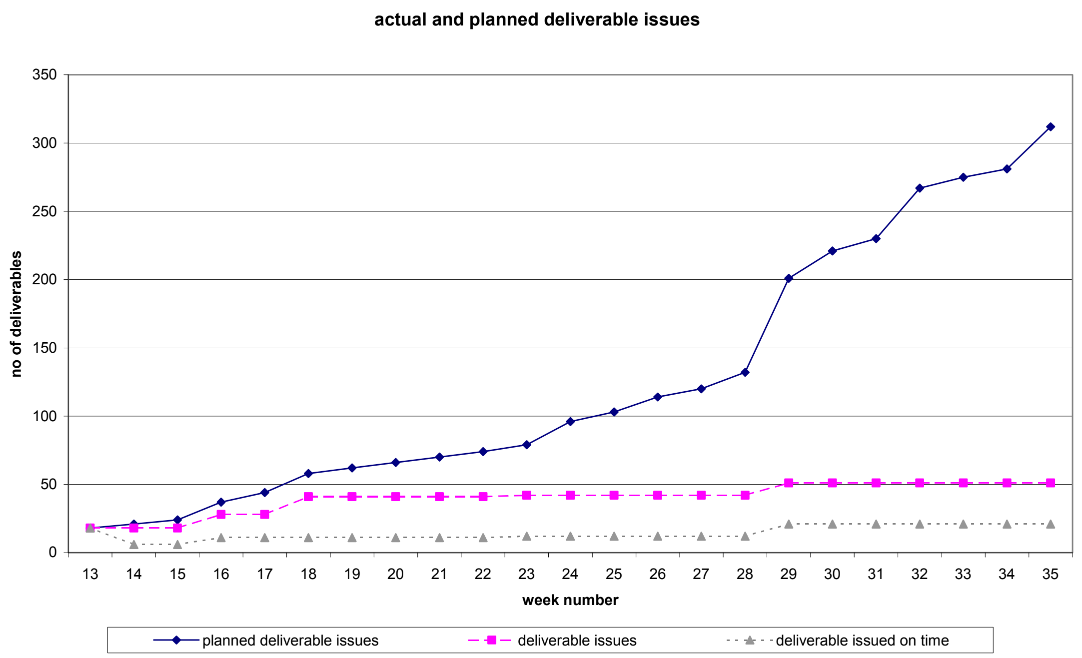

Figure 2: Example DPPI actual and planned deliverable issue

In conclusion, the barriers identified during the transformation of raw data to DPPIs can be addressed by combination of simple linked spreadsheets to collect, transform and present the DPPIs and ensuring that the formats of raw data sources are standardised on projects. However, future work should focus on making the data collection and transformation process more robust.

Applicability of Design Process Performance Indicators

The practitioner review of DPPIs provided some positive encouragement for practical deployment of the DPPIs. The average rating scores shown on Table 5 indicates that 11 of the 15 proposed DPPIs are at least important if not essential to monitoring the design process and therefore should form the basis of any practical deployment of DPPIs. These were indicators associated with the deliverable production process, use of staff resources and the impact of design changes.

Practitioners also commented on the benefits of each DPPI, which are summarised in Table 5. Practitioners particularly liked the graphical presentation of the deliverable DPPIs stating that they give a clear indication of performance and could be used to help decide future deliverable issue rates. The productivity indicator was considered a useful reporting measure for illustrating the cost effectiveness of project parties in producing their deliverables. Furthermore, the presentation of all DPPIs in a single report was considered to simplify use and reporting. The DPPIs: % of planned deliverables approved for construction, and average delay in achieving approval were deemed to have the potential to create a focus on the key project goal of timely deliverable production. The average comment issuing delay was considered useful for highlighting the potential impact that those reviewing deliverables have on design process efficiency.

While the DPPI: % content completeness of issued deliverables was considered important because it illustrated where issued deliverables require updating, it was also noted that deliverable completeness is not always monitored, which might restrict the opportunity to prepare a DPPI using such data. However, where this practice has been employed, practitioners have found it a useful deliverable reviewing tool. Therefore it is expected that practitioners would be willing to monitor deliverable completeness. It was suggested that while it might be problematic to isolate impact of a change for DPPI: % project overrun due to design rework, it was important for preventing future changes by highlighting the impacts or previous changes. A similar attitude was shown to the DPPI: % project overspend due to design rework. The difficulty in isolating design change impacts is addressed by change control processes that require an explicit analysis of all design change impacts. DPPI: % of planned manhour costs was considered an important DPPI as it could be used as an early warning tool to assess whether current resource levels were sufficient to meet future deliverable issue levels.

Measures associated with the control of RFIs were considered to reinforce the importance of hitting required issue dates yet were DPPIs that were "nice to have" rather than important for monitoring design process performance. This suggests while they are useful indicators they are unlikely to be the headline performance measures for practitioners – a view reinforced by practitioners' comments that such indicators do not relate to a key issue. Practitioners viewed the average no. of revisions per deliverable in a similar way.

In conclusion, the 11 indicators associated with the deliverable production process, use of staff resources and the impact of design changes should form the basis of any practical deployment of DPPIs. This still ensures that the process characteristics presented by Oakland and Sohal (1996) are still satisfied and thus the DPPIs still represent a comprehensive illustration of design process performance. However, further investigation of these indicators is necessary to determine the true value of each DPPI in helping to monitor design process performance and to identify and address any barriers preventing the implementation and use of the DPPIs.

6. CONCLUSIONS

This paper has reported on the development of a suite of design process performance indicators (DPPIs) within a major UK civil and building design and construction company. This research has led to several conclusions.

A Performance Indicator Framework helps to prepare a comprehensive set of performance indicators.

Many factors must be considered when designing performance indicators to avoid adversely influencing practitioners' behaviour or developing a system that no one will use.

No current design performance measurement initiative sufficiently covers all design process characteristics to be a comprehensive representation of design process performance.

It is possible to collect and convert relevant raw project data into design process performance indicators with no additional work outside practitioners' normal project tasks.

It is possible to develop a suite of performance indicators using standard project information, processes and software that represent a comprehensive picture of design process performance with no additional work outside practitioners' normal project tasks.

Practitioners consider DPPIs relating to the deliverable production process, impact of design change and staff resource indicators important to monitor design process performance yet remain unconvinced by indicators relating to the control of RFIs.

There is a need to establish an appropriate set of DPPI targets dependent on project conditions.

There is a need to research the real experience of the application of DPPIs in industry practice to test and refine suitable performance indicators for the construction design process.

7. REFERENCES

Alarcon, L.F., 1996, “Performance Measuring Benchmarking and Modelling of Construction Projects”, *Proceedings of the 4th International Group for Lean Construction Conference, Birmingham, UK.*

Austin, S.A., Baldwin, A.N., Newton, A.J., 1996. “A data flow model to plan and manage the build design process”, *Journal of Engineering Design*, Vol. 7, No. 1, pp 3-17.

Austin, S.A., Baldwin, A.N., Newton, A. J., 1994, “Manipulating data flow models of the building design process to produce effective design programmes*”. Proceedings of ARCOM Conference,* Loughborough, UK, pp 592-601.

Austin S, Baldwin A, Newton A.J, 1993, *“*Modelling Design Information in a Design and Build Environment*”, Proceedings of ARCOM Conference,* Salford, England*,* pp 73-84.

Bibby, L., Austin, S., Bouchlaghem, N., 2002, “Defining an improvement plan to address design management practices: a case study of a UK construction company”, *International Journal of IT in Architecture, Engineering and Construction* (*IT-AEC),* Accepted for publication in early 2003.

Bourne, M., Mills, J., Wilcox, M., Neely, A., Platts, K., 2000, “Designing, implementing and updating performance measurement systems”, *International Journal of Operations and Production Management*, Vol. 20, No. 7, pp. 754-771.

Brunso, T.P., and Siddiqi, K.M., 2003, “Using Benchmarks and Metrics to Evaluate Project Delivery of Environmental Restoration Programs”, *Journal of Construction Engineering and Management*, Vol. 129, No 2.

BRE, 2000, CALIBRE2000, www.calibre2000.com

Camp, R.C., 1995, *Business Process Benchmarking: Finding and Implementing Best Practices*, ASQC Quality Press, Wisconsin.

Camp, R.C., 1989, *Benchmarking: the Search for the Industry Best Practice that Leads to Superior Performance*, Quality Press, Madison, Wisconsin.

Carpinetti, L. C.R. and de Melo, A. M., 2002, “*What to benchmark? A systematic approach and cases*”, Benchmarking: An International Journal, Vol. 9 No. 3, pp. 244-255.

CIRIA, 2000, *Management of technical excellence within design organisations*, Report C531, CIRIA, London.

CIRIA, 2003, Consultant Key Performance Indicators, www.kpizone.com

Cockshaw, Sir A., 2001, Changing Construction Culture. In *Interdisciplinary design in practice*, (eds. R. Spence, S. Macmillan, and P. Kirby), Thomas Telford, London, pp 15-21.

Construction Industry Institute / European Construction Institute, 2002, Benchmarking Initiative, www.eci-online.org/

Construction Industry Institute, 1999, Project Definition Rating Index for Building Projects, Implementation Resource 155-2, Austin, Texas, US.

Construction Industry Council, 2002, Design Quality Indicators, www.dqi.co.uk

Cornick, T.: *Quality management for building design*, Butterworth, London, 1991, pp 218.

Cox, I. and Morris, J., 1999, "Process mapping: a quantitative study of post contract award design changes in construction", School of Industrial and Manufacturing Science, Cranfield University.

Cox, A. and Thompson, I. (1998), "On the appropriateness of benchmarking"*, Journal of General Management*, Vol. 23 No. 3.

Crawford, K.M. and Cox, J.F., 1990, "Designing performance measurement systems for just-in-time operations*", International Journal of Production Research*, Vol. 28 No. 11, pp. 2025-2036.

Dent, R.J., and Alwani-Starr, G., 2001, *Performance Measurement of Design Activities – A summary report and key performance indicators*, CIRIA publication FR/IP/44.

Edlin, N., 1991, "Management of engineering/design phase", *Journal of Construction Engineering and Management*, ASCE, Vol. 117, No.1, pp 163-175.

Eppinger, S.D., 2001, "Innovation at the Speed of Information", *Harvard Business Review*, Vol. 79, Issue 1, pp 149-158.

Fellows, R. and Liu, A. 1997, *Research Methods for Construction*, Blackwell Science, Oxford.

Fortuin, L., 1988, "Performance indicators – why, where and how?", *European Journal of Operational Research*, Vol. 34 No. 1, pp.1-9.

Freire, J. and Alarcon, L.F. 2000, "Achieving a lean design process" in *Proceeding of the 8th International Group for Lean Construction Conference*, Brighton, England.

Frost, R.B. 1999, "Why does industry ignore design science", *Journal of Engineering Design*, Vol. 10, No. 4, pp 301-304.

Globerson, S., 1985, "Issues in developing a performance criteria system for an organisation", *International Journal of Production Research*, Vol. 23 No. 4, pp. 639-646.

Gray, C., Hughes, W., 2001, *Building Design Management,* Butterworth Heinemann, Oxford.

Hammond, J., Choo, H. J., Austin, S., Tommelein, I.D., Ballard, G. 2000, "Integrating design planning, scheduling, and control with Deplan" in *Proceedings of the 8th International Group for Lean Construction Conference*, Brighton, England.

Hauser, J.R., 2001, "Metrics Thermostat", *Journal of Production Innovation Management*, Vol. 18.

Hinton, M., Francis, G. and Holloway, J., 2000, "Best practice benchmarking in the UK", *Benchmarking: An International Journal*, Vol. 7 No. 1, pp. 52-61.

Hopwood, A.G., 1984, *Accounting and Human Behaviour*, Prentice-Hall, Englewood Cliffs, New Jersey, USA.

Kanter, J., 2000, "Have we forgotten the fundamental IT enabler: ease of use", *Information Systems Management*, Vol., 17, Pt. 3, pp 71- 77.

Khurrum S. Bhutta and Faizul Huq, 1999, "Benchmarking - best practices: an integrated approach", *Benchmarking: An International Journal*, Vol. 6 No. 3, pp. 254-268.

Koskela, L., 1999, "Management of production in construction: a theoretical view", *Proceedings of the 7th International Group for Lean Construction Conference,* University of Berkeley, California, USA.

Koskela, L., Ballard, G., Tanhuanpaa, V-P. 1997, "Towards lean design management" in *Proceedings of the 5th International Group for Lean Construction Conference*, Gold Coast, Australia.

Lafford, G., Penny, C., O'Hana, S., Scott, N., Tulett, M., Buttfield, A., 1998, *Managing the Design Process in Civil Engineering Design and Build - a guide for Clients, Designers and Contractors, Funders Report CP/59*, Construction Industry Research and Information Association, London.

Lantelme, E. and Formoso, C.T., 2000, "Improving performance through measurement: the application of lean production and organisational learning principles", *Proceedings of the 8th International Group for Lean Construction Conference*, Brighton, England.

Lee, A., Cooper, R., and Aouad, G., "A methodology for designing performance measures for the UK construction industry", *Bizarre Fruit Postgraduate Research Conference on the Built and Human Environment*, Salford, UK

Love, P.E.D., Smith, J., Li, H., 1999, "The propagation of rework benchmark metrics for construction", *International Journal of Quality and Reliability Management*, Vol. 16, No. 7., pp 638-658.

Lynch, R.L. and Cross, K.F., 1991, *Measure Up – The Essential Guide to Measuring Business Performance*, Mandarin, London.

Maskell, B.H., 1991, *Performance Measurement for World Class Manufacturing*, Productivity Press, Portland.

Miles, R..S., 1998, "Alliance Lean Design / Construct on a Small High Tech. Project", *Proceedings of the 6th International Group for Lean Construction Conference*, Guaruja, Brazil.

Mohamed, S., 1998, "Benchmarking and Improving Construction Productivity", Benchmarking for Quality Management and Technology, Vol. 3, No. 3, pp50-58.

Morris, J., Rogerson, J., Jared, G., 1999, "A tool for modelling the briefing and design decision making processes in construction", *School of Industrial and Manufacturing Science*, Cranfield University, Cranfield, UK.

Neely, A., 1998, "*Three modes of measurement: theory and practice*", International Journal of Business Performance Management, Vol. 1, No. 1.

Neely, A., Richards, H., Mills, J., Platts K. and Bourne, M., 1997, "Designing performance measures: a structured approach*", International Journal of Operations & Production Management*, Vol. 17 No. 11.

Oakland, J. and Sohal, A., 1996, *Total Quality Management: Text with Cases*, Butterworth Heinemann, Melbourne, Australia.

Prescott, Rt. Hon. J., (1999), Department of Transport and the Regions press release, 19 July 1999.

Race, P. 2001, *2000 Tips for Lecturers*, Kogan Page, London.

Sink, D.S., 1985, *Productivity Management: Planning, Measurement and Evaluation, Control and Improvement*, John Wiley, New York.

Songer, A.D., Diekmann, J., Hendrickson, W., Flushing, D., 2000, "Situational re-engineering: case study analysis", *Journal of Construction Engineering and Management,* ASCE, Vol. 126, No. 3, pp 185-190.

Strassman, H.B., 1995, "*A bias for action*", ENR McGraw-Hill Companies, Inc. pp 28-32.

Tluazca, G.J. and Daniels, S.H., 1995, "*A market measured in microns and megaprojects*" ENR, McGraw-Hill Companies Inc, pp 34-38.

Torbett, R., Salter, A.J., Gann, D.M., Hobday, M., 2001, "*Design performance measurement in the construction sector: a pilot study*", Submitted to IEEE Transactions of Engineering Management.

Treasury Task Force, 2000, How to Achieve Design Quality in PFI Projects, Technical Note 7, HM Treasury.

Walsh. P., 2000, "How to assess performance targets and how to assess performance against them", *Benchmarking: An International Journal*, Vol. 7 No. 3, pp. 183-199.

Womack, J. P. and Jones, D. T., 1996, *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*, Simon & Schuster, Sydney.

Zairi, M., 1996, *Benchmarking for Best Practice – Continuous Learning Through Sustainable Innovation*, Butterworth-Heinemann, Oxford, UK.