Loughborough University

This item was submitted to Loughborough's Research Repository by the author.
Items in Figshare are protected by copyright, with all rights reserved, unless otherwise indicated.

Delivering learning and tools to improve design management in practice

PLEASE CITE THE PUBLISHED VERSION

PUBLISHER

© CIB

VERSION

AM (Accepted Manuscript)

LICENCE

CC BY-NC-ND 4.0

REPOSITORY RECORD

Bibby, Lee, Dino Bouchlaghem, and Simon A. Austin. 2019. “Delivering Learning and Tools to Improve Design Management in Practice”. figshare. https://hdl.handle.net/2134/5043.

Loughborough University

This item was submitted to Loughborough's Institutional Repository (https://dspace.lboro.ac.uk/) by the author and is made available under the following Creative Commons Licence conditions.

creative commons

COMMONS DEED

Attribution-NonCommercial-NoDerivs 2.5

You are free:

- to copy, distribute, display, and perform the work

Under the following conditions:



Attribution. You must attribute the work in the manner specified by the author or licensor.



Noncommercial. You may not use this work for commercial purposes.



No Derivative Works. You may not alter, transform, or build upon this work.

- For any reuse or distribution, you must make clear to others the license terms of this work.
- Any of these conditions can be waived if you get permission from the copyright holder.

Your fair use and other rights are in no way affected by the above.

This is a human-readable summary of the Legal Code (the full license).

Disclaimer

For the full text of this licence, please go to:
http://creativecommons.org/licenses/by-nc-nd/2.5/

DELIVERING LEARNING AND TOOLS TO IMPROVE DESIGN MANAGEMENT IN PRACTICE

LEE BIBBY, DINO BOUCHLAGHEM AND SIMON AUSTIN

Centre for Innovative Construction Engineering, Loughborough University,
England, United Kingdom

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-five 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.

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 uncoordinated decision making ((Austin, Baldwin and Newton, 1996), (Cornick, 1991), (Hammond *et al*, 2000), (Koskela, Ballard and Tanhuanpaa, 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 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-five 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.

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.

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
- 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.

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
- Forces unwanted discipline on practitioners

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

- Suitably developed for industry application
- Carefully deployed within practice
- Written in a language that practitioners could relate to
- User friendly
- Focused on pragmatic outcomes
- 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).
- identify effective design management practices and help shape content of design management tools (effective ways of managing the process).
- 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.

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-five 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:

- 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.
- 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 lexicon used to group and describe these tools in the handbook is shown by Figure 1.

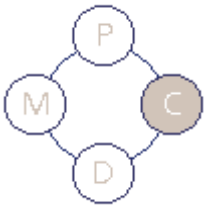


Figure 1: *Design management tool lexicon*

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 "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 2.

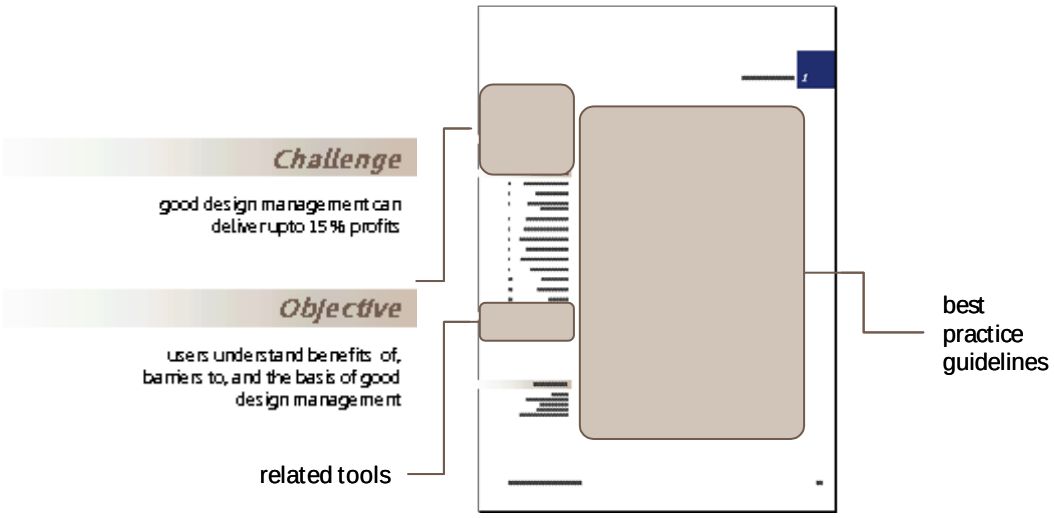


Figure 2: *Handbook chapter format*

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.
- 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 3 to 6 inclusive.

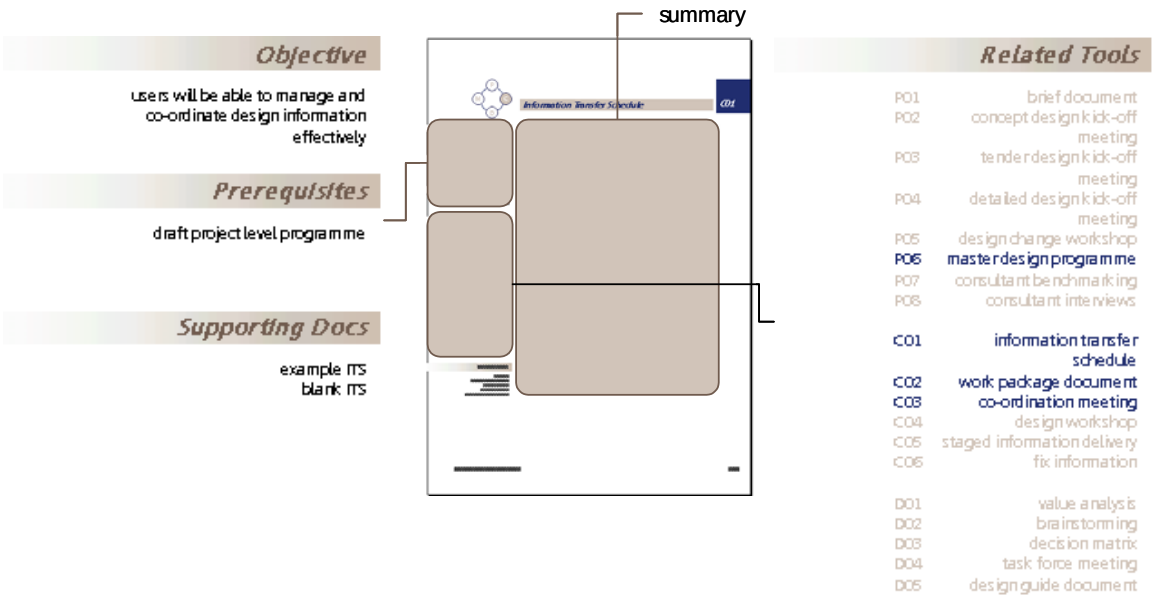


Figure 3: *Tool front page format*

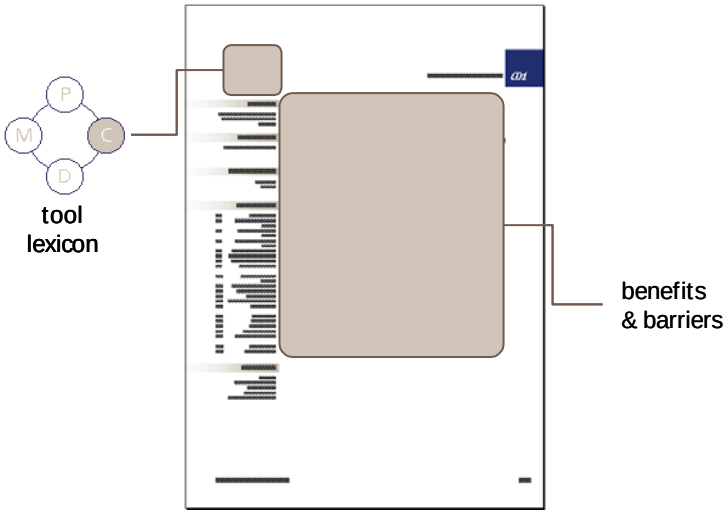


Figure 4: *Tool benefits and barriers*

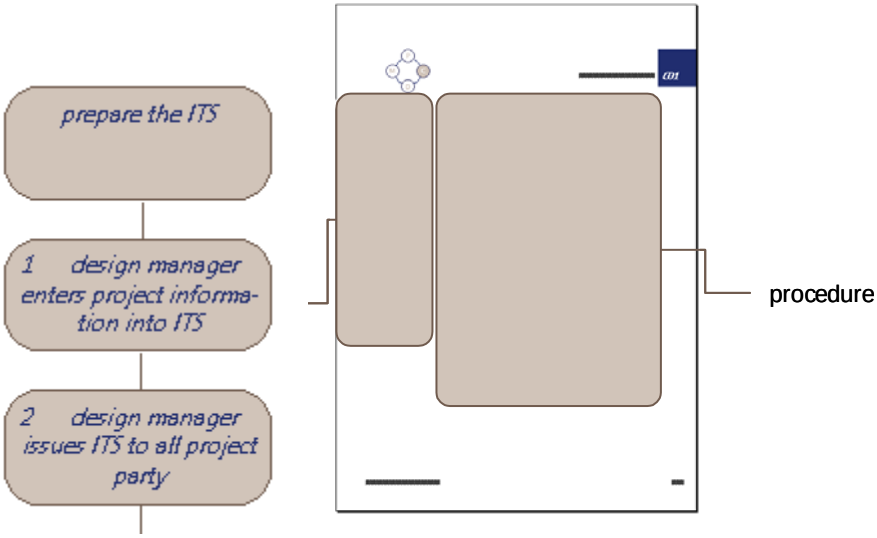


Figure 5: *Tool procedure and flowchart*

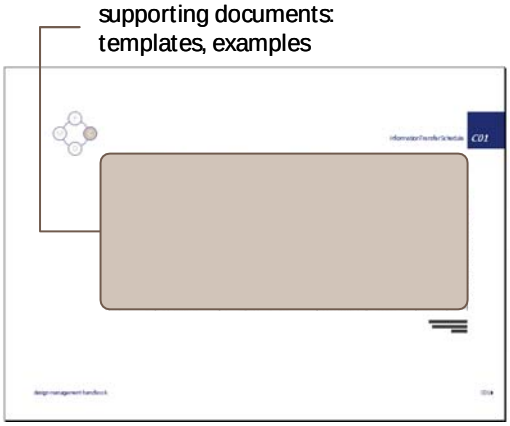


Figure 6: *Example of supporting material*

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. An example of a tool selection table is shown by Figure 7.

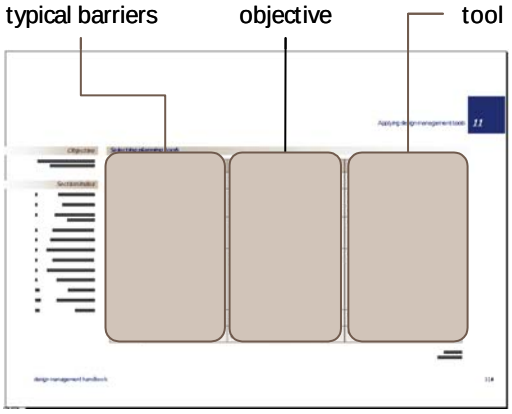


Figure 7: *Tool selection table*

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.

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.
- 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.

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.

Detail specifically what aspects of the project performance will be monitoring and why:

- no. of information packages issued / wk
- no. of deliverables issued / wk
- RFI / TQ responses issued / wk
- information package waiting time
- deliverable issue waiting time
- RFI / TQ response waiting time
- resource use / wk
- staff turnover / wk
- average time for design rework
- average cost of design rework
- (information packages issued / wk) / resource use
- (deliverables issued / wk) / resource use
- average deliverable production cost
- average no. of revisions / deliverable

explain that will be collecting project information on a range of performance indicators to:

- see what information is / is not easy to collect
- see what information usefully represents an efficient / effective process
- act as a benchmark for future design processes

Explaining will be collecting information on control projects as a benchmark comparison.

Explain that very few project undertaken that focus on the actual performance of the design process – mostly focus on cost/time/quality performance of consultants. This will form a significant research activity itself. A key finding of work by Cox and Morris (1999[1]) is the difficulty involved in collating data that give rise to metrics which are obvious from a process management perspective (and, indeed, which are readily and routinely available in the manufacturing sector). This could be due to the apparent lack of a desire within the construction sector to advance process understanding in an appropriate way.

CURRENT RESEARCH STRATEGY

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

- training workshops delivered across the organisation
- 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.

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.

Initial workshop given – results of workshop to be provided. Explain what Skanska Construction believe they need (tools and practices) to help them manage the design process. i.e. what do companies who manage the design process need to focus on and the types of tools they need to support them in the range of activities they undertake.

Improvement team review of workshop and handbook content. Include comments and analysis of findings from this exercise:

- content of design management handbook sections and tools

- level of design management educating required by practitioners
- could compare back to past research done in literature review and initial study (i.e. what should design management include).
- discuss barriers to new tools as identified by Skanska UKB staff (i.e. complexity of tools, barriers due to procurement route, amount of work needed to use tool, collaboration of various parties for success of tool).
- Identify how handbook has been modified to meet the requirements of Skanska UKB.

Improvement team review of workshop delivery. Include comments and analysis of findings from this exercise:

- comments on workshop format
- interactivity / involvement
- learning strategies applied (presentation / discussion / problem solve)
- handbook presentation / layout and structure

PROJECT IMPLEMENTATION

Need to revise details of project where tools being trailed.

The design management training initiative is also being trialled 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 trialled.

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
- 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
- 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.

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
- identifying improvements to existing design management tools and techniques

FUTURE RESEARCH STRATEGY

The comments, views and data collected from the implementation of the training initiative are currently being collected to modify the training delivery to suit the needs of practitioners. Such 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
- a discussion forum to promote interest in design management within the company and for practitioners to share design management ideas and success stories

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
- 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.

Conclusions on process metrics

Conclusions on content of training programme:

- level of design management educating required by practitioners
- design management support required by practitioners
- handbook and workshop content
- suitability for design management in design and build / innovated design and build / traditional
- potential for successful application of tools

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.

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.

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.