

DESIGN MANAGEMENT IN A CONSTRUCTION COMPANY

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1 Abstract

Design Management is an increasingly important function in the construction industry. Design management is being done by construction companies because of the failure of other existing systems to achieve proper integration of the design and construction processes.

Initial results from a three-year empirical study of the practice of design management in an international construction company have been compared to conceptions devised from literature in order to describe the design management practices. This is being done in order to provide a foundation, which can be used to generate better co-ordinated design and construction in complex one-off engineering projects.

Three conceptions of design management: design management as “integrators of design and construction”; design management as “managers”; and design management as “meta designers” were devised from literature and compared to several case studies conducted on a variety of projects.

Early results indicate that during the operational stages of a project design management in the company can be better conceived as “meta designers” rather than as “managers”. The design management personnel were responsible for designing a system, which made stakeholders the co-developers or co-designers; they did tasks that designers are responsible for in smaller projects, but which inevitably get lost in larger projects; and they dealt with issues arising from the integration of design and construction.

2 Introduction

The paper presents initial results from a three-year empirical study of the practice of design management in an international construction company. The objective of the project is to describe in detail design management practices in a construction company. This will provide a foundation, which can be used to generate better co-ordinated design and construction in complex one-off engineering projects.

Three conceptions of design management: design management as “integrators of design and construction”; design management as “managers”; and design management as “meta designers” have been devised and compared to several case studies conducted on a variety of projects. These studies indicate that design management in the company in the operational stages of a project are better conceptualized as “meta designers” rather than “managers” and that they deal with issues arising from the conception of design managers as “integrators of design and construction”

3 Background

Design Management is an increasingly important function in the construction industry. Projects are becoming more complex and global and new contractual arrangements, which require alliances and partnerships between designers and constructors are increasingly used [1-3]. Gray [2] suggests that design management is being done by construction companies because of the failure of other existing systems to achieve proper integration of the design and construction processes.

In complex one-off projects most of the design detail was traditionally completed before obtaining an estimate to construct the project. From the 1900's to the 1980's this procedure of design-bid-build was the predominant one in use and personnel in the construction industry were trained with this assumption in mind [4-6].

From the 1980's the construction industry has been increasingly pressured to participate in new project acquisition processes and has had to take on and estimate projects in which the design is not yet complete [1, 6-8]. This is being done in order to reduce the total project time for several reasons: 1) because design can be completed while construction is being undertaken and thus potentially be completed faster; 2) to increase the constructor's accountability for design; and 3) to generate a less adversarial working environment. That ideally means a collaborative or integrated approach be undertaken by design and construction [3]; or a concurrent approach where design is done just in time for procurement and construction [7].

These highly complex, multi-stakeholder projects change fundamentally the dynamics of the relationship between design and construction and the management of activities between the two [1, 7, 9]. In earlier times when design was completed before construction, design management was largely about the management of designers in an architectural or engineering consultancy. This was a relatively contained activity that focused on the production of design documents for the client. With the rise of new contractual arrangements, design management now involves a much more complex set of relationships between the client and specialists from design consultancies, vendors, manufacturers and constructors. Correspondingly the functions of design management are much broader and much less well defined. It is this conception of design management that the construction companies, rather than design consultancies, are taking responsibility for in increasing numbers.

4 Theory

There has been very little empirical research on design management, even that undertaken in traditional design consultancies, and almost nothing in relation to design management in complex one-off projects involving fast tracking and new types of contractual relationships.

Some insights into the roles and responsibilities of design management in complex one-off projects in the construction industry were derived by extrapolation from published case studies of engineering designers in practice and of design management in other engineering contexts, in particular the manufacturing industry. These studies and research done to date lead to the development of three different conceptions of design management in the construction industry. The three conceptions of design management in the construction industry devised were: 1) design management as “integrators of design and construction”; 2) design management as “managers”; and 3) design management as “meta designers” as explained in sections 4.1, 4.2 and 4.3.

The tasks and responsibilities arising from these three conceptions have been compared to actual design management tasks and responsibilities in practice within a construction company in order to determine their applicability to design management in the construction industry. Depending if the tasks prevalent in these concepts are observed or not it should be possible to see which job functions design management is meant to fulfil and thus which concept is most applicable to design management in the construction industry.

4.1 Design Management as Integrators of Design and Construction

Design management in the construction industry has been conceptualised as a role for integrating design and construction with the term “integrators of design and construction”. Table 1 summarises the traditional ways of delivering construction projects - the design-bid-build approach compared to new ways of delivering projects - integrated design and construction approaches. Column 1 in Table 1 represents serial design and construction, i.e. design-bid-build project delivery. Column 2 in Table 1 represents the integrated design and construction approaches, i.e. design-build, design and construct, fast-tracking, concurrent design and construction, and collaborative design and construction. Column 3 in Table 1 predicts the problems and issues in the construction industry if the serial design-bid-build mentality is applied in these new integrated ways of project delivery. Column 4 in Table 1 describes the design management functions in such an environment. If design management undertakes these responsibilities in their approach to the task of design management in practice it may be conceived that the primary role of design management is to integrate design and construction.

Table 1 Issues and Functions arising due to the shift from Serial to Integrated Design and Construction (D&C)

Serial D&C	Integrated D&C	Issues.	Functions:
Serial models of the design and construction processes [4, 7, 10].	Concurrent or integrated models of the design and construction processes [7].	Design is expected to be done in a serial fashion and completed before construction begins restricting the use of integrated techniques.	Integrating design and construction. Ensuring the concurrent or integrated concept is understood.
Construction doesn't begin until the design is finalised.	Construction and design are done together.	Constructors would not expect to interact with designers. Constructors would not expect designers to have input into their processes.	Integrating design and construction by ensuring that constructors interact with designers and designers interact with construction.
Information upfront. Design has been finalised. Procurement is planned in advance.	Less information early, design and procurement is done on the run or just in time [14, 15].	Not tolerant of receiving information at the last minute. Low tolerance of design on the run or just in time design documents and procurement.	Ensuring the project team is prepared for last minute information and just in time design and procurement.

Serial D&C	Integrated D&C	Issues.	Functions:
<p>Estimate is based on a detailed design.</p>	<p>Estimate is based on an ambiguous concept [11].</p>	<p>People would try to stick with the original estimates; hence estimators / tender writers become the designers.</p> <p>Estimating is done as if based on a detailed design.</p> <p>Estimates are assumed to be exact [11].</p> <p>Estimators don't expect to be designers.</p>	<p>Ensuring estimators have the initial design information required.</p> <p>Assessing the estimators estimate and skills [11].</p> <p>Avoiding designs being limited by poor original estimates [11].</p> <p>Dealing with client and constructor concerns about design and budget differences.</p> <p>Ensuring systems are in place to enable design progression.</p>
<p>Design costs are fixed and upfront.</p>	<p>Design costs are flexible.</p>	<p>Not tolerant of changing design costs.</p>	<p>Ensuring the project team is prepared for changing costs of the design and the design effort.</p>
<p>A kind of push system, where design and construction deliverables are planned in advance [16].</p>	<p>A kind of pull system, where design deliverables are made pending on what construction requires and how the design develops [16].</p>	<p>Construction expects deliverables in advance.</p>	<p>Ensuring construction has what they require according to the way the design develops.</p>
<p>Design is fully documented in order to convey and hold the design intent.</p> <p>Design hands over detailed design documents to construction.</p>	<p>Design intent is conveyed by the most efficient method available.</p> <p>Design and construction collaborate.</p>	<p>Document deficiency is viewed as design deficiency [12, 13].</p>	<p>Ensuring efficient conveyance of the design intent by the most efficient method.</p> <p>Ensuring that design is not deficient, no matter how it is delivered.</p>

Serial D&C	Integrated D&C	Issues.	Functions:
<p>Design management is done at the design consultancy.</p>	<p>Design management is integrated for the whole project.</p>	<p>Construction expects no responsibility for design management.</p> <p>There is no career path or training for design management at the construction company.</p> <p>Procedures for design management at the construction company are based on traditional construction ideas.</p>	<p>Ensuring design management is integrated for the whole of project.</p> <p>Ensuring construction accepts responsibility for design management.</p> <p>Ensuring training programs and procedures are adequate.</p> <p>Ensuring the company procedures are up to date.</p>
<p>Construction techniques are planned.</p>	<p>Construction techniques are flexible.</p>	<p>Construction milestones and critical path are considered absolute.</p> <p>Planning is considered absolute.</p>	<p>Ensuring construction milestones, critical path, planning and construction techniques are flexible.</p> <p>Ensuring construction are ready to change their techniques.</p>
<p>Constructors are known for construction. Designers for designing.</p>	<p>Constructors have input into the design and designers have input into construction techniques.</p>	<p>Constructors do not give input into the design and designers do not have input into construction techniques.</p>	<p>Ensuring collaboration between constructors and designers.</p> <p>Ensuring constructors have input into the design and that designers have input into construction techniques.</p>
<p>Adversarial relationship between construction and designers.</p> <p>Arbitration is used to solve problems [9].</p>	<p>Empathetic relationship between construction and designers.</p> <p>Problems are solved by participation [9].</p>	<p>Last minute design changes are made because constructors only give design input at the time when the design doesn't work to hold design responsible for problems.</p>	<p>Ensuring constructors have timely input into design.</p> <p>Ensuring problems are solved by participation.</p>

Serial D&C	Integrated D&C	Issues.	Functions:
Design is known.	Design is unknown, ambiguous and changing.	Low tolerance of the unknown, changes and design ambiguity.	Ensuring unknown design, design changes and ambiguity are expected.
<p>In order to generate profit efficient productive construction and savings made on the original bid is required.</p> <p>Thus speed, decisiveness and hidden savings are required.</p> <p>Having the design means that decisions based on technical design knowledge are well regarded.</p>	<p>In order to be more productive and efficient collaboration is required between design and construction.</p> <p>Intimate knowledge of where each activity is at and what it's going to produce and need is required.</p> <p>Savings can be made with collaborated design, design for construction and innovative design throughout the project.</p>	<p>Construction work is begun ASAP.</p> <p>Constructors tend to make crucial decisions.</p> <p>Technical knowledge of the design and how to save on it is regarded.</p> <p>Actions, speed, decisiveness and hidden savings are valued over improvements such as resulting from innovative major design changes and collaborated design.</p> <p>Minimal interest in finding out the progress of each other's activities.</p>	<p>Ensuring consultation between construction and design before beginning construction.</p> <p>Ensuring designers ideas are included in crucial decision making.</p> <p>Ensuring improvements resulting from major design changes, collaborated design and design for construction are valued.</p> <p>Ensuring that constructors and designers are aware of each other's progress.</p>
<p>Designers work in a serial fashion (gather data, analyse data, formulate solution, implement solution) [17].</p> <p>Designs have an ultimate solution [18].</p> <p>Engineering is considered an exact science [19].</p>	<p>Designers work in a solution orientated, integrated environment [20].</p> <p>Designers propose experiment learn again and again with the project team [21].</p> <p>Designs have no ultimate solution [18].</p> <p>Engineering is not considered exact, but as a prediction, estimation or plan.</p>	<p>In an integrated project construction may be used to in collaboration with design, to do for example design trials. Construction views this as design deficiencies, unnecessary work or rework.</p> <p>Rework is viewed as design deficiency.</p> <p>Assumptions made about design being right the first time.</p>	<p>Ensuring collaboration and trial designs are expected, especially where innovation or newer technology is utilized.</p> <p>Making allowances for design trials.</p> <p>Preparing for design failures.</p>

4.2 Design Management as Managers

A conception taken in this project and the conventional conception taken in literature is that design management is a division of management [22]. The following conceptions: design management as a division of project management; design management as managing design; and design management as task management, flow management and value management were conceived under this category.

4.2.1 Design Management as a Division of Project Management

Design management is conceived particularly in the construction industry as a division of construction project management. As construction project management is based on things such as construction schedule planning and monitoring, critical path, and machine productivity then they expect design management to do this in terms of design. Examples of the tasks and responsibilities are; tactics for developing a project culture; defining the tasks; managing information production; evaluation of information; and planning, monitoring and control [23].

4.2.2 Design Management as Managing Design

Design management in the manufacturing industry is considered as a process of managing design. It is assumed that design management is responsible for managing the design and the design process. It is supposed that design management should have intimate knowledge of that process in order to manage it and they are also expected to know what designers do and be able to manage both designers and the design process.

Hales [24] suggests that successful management of the design process boils down to the effective handling of three issues: 1) activities of the design team, 2) output from the design team and 3) influences on the design team. Cooper & Press [25] suggest design management are responsible for 1) developing a matrix for managing design, because it involves a number of organisational levels and activities; 2) planning design, which involves including design in organisational goals, strategies and policies for design, and putting process in place for using design; 3) organising for design, which means having the right structure, choosing the right teams, using training and development programs and investing in design; 4) implementing and monitoring design, which involves implementing and monitoring design programmes and projects; and 4) evaluating design including evaluating the management of design and design projects. Along the same lines Cross [20] suggests that design management is responsible for design strategies and tactics as well as product development, planning and innovation.

4.2.3 Design Management as Task, Flow and Value Management

Another conception is that design management can be conceived in three different ways 1) as a process of converting inputs into outputs (Task management), 2) as a flow of materials and information through time and space (Flow management) and 3) as a process of generating value for customers (Value management). This conception has been adopted from theories of production and has been applied to construction [26], project management [27] and design management [28]. The methods and practices of design management suggested in Ballard [22] are for the conversion view: work breakdown structure; critical path method; and organizational responsibility chart; for the flow view: rapid reduction of uncertainty; team approach; tool integration; and partnering; and for the value generation view: rigorous requirement analysis; systematized management of flow down of requirements and optimisation.

4.3 Design Management as Meta Designers

Initial observations of design management revealed tasks being done that did not fall under the “management” conception and were perhaps in the domain of designers on smaller design projects. Dorst [21] suggests that when projects become large major design projects the kind of comprehensive overview that designers need to possess in smaller projects inevitably gets lost.

Meta designers, which are used in the IT industry design things so that the users become the designers and as such they design the design system rather than design a system. That then incorporates users as co-developers or co-designers [29]. The definition used here is that “meta design” is about incorporating others such as stakeholders, consultancies and sub-contractors as co-developers or co-designers, designing the design system and doing tasks which were perhaps in the domain of designers on smaller projects. Examples of tasks from Dorst [21] that designers have in smaller projects, which design management in larger projects take on are; integration of the various demands of the project’s stakeholders; interaction with groups of people that have different ways of looking at the design problem; determining design strategies; balancing design risk; coping with skinny projects; and taking into account the larger whole.

5 Research Method

The tasks and practices of design management have been examined by gathering empirical data in a series of case studies of design management in complex one-off construction projects in industry. The research method is based on case study research [30]. The method used for case study data collection and analysis is depicted in figure 1. This figure is similar to that described for data convergence by Yin [30]. Each of the key concepts in case study research: document analysis; observation; participant observation; interviews; surveys; and literature reviews, as shown in figure 1, has been achieved by analysing the direct inputs in figure 1 from the different case studies as described in section 5.1. Several case studies on various complex one-off engineering projects are being done in order to converge the data and to determine the domain in which the results pertain to design management in the construction industry. Literature reviews have complemented this and will also be used to determine if the results pertain to design management outside the construction industry.

In order to analyse the information items such as key event logs, grouping of data with suitable data variables, journals, summaries etc. as shown in direct outputs figure 1 were devised. Each output and ongoing analysis has been an influence on the next set of information gathered. This is done in order to obtain the relevant data required within the 3 year study period. Case studies thus far have been analysed with methods including organizing data into key performance indicators and comparing them in order to see data patterns and organizing data in relevant groups determined by the main issues discussed. Surveys questions have been ordered and ranked according to number of responses and the questions grouped according to economic context, general job function, division within company and project stage. All results have been discussed at meetings with university researchers and with design managers within the company for verification. Items such as concept diagrams, data patterns and statistics have been devised from such analysis.

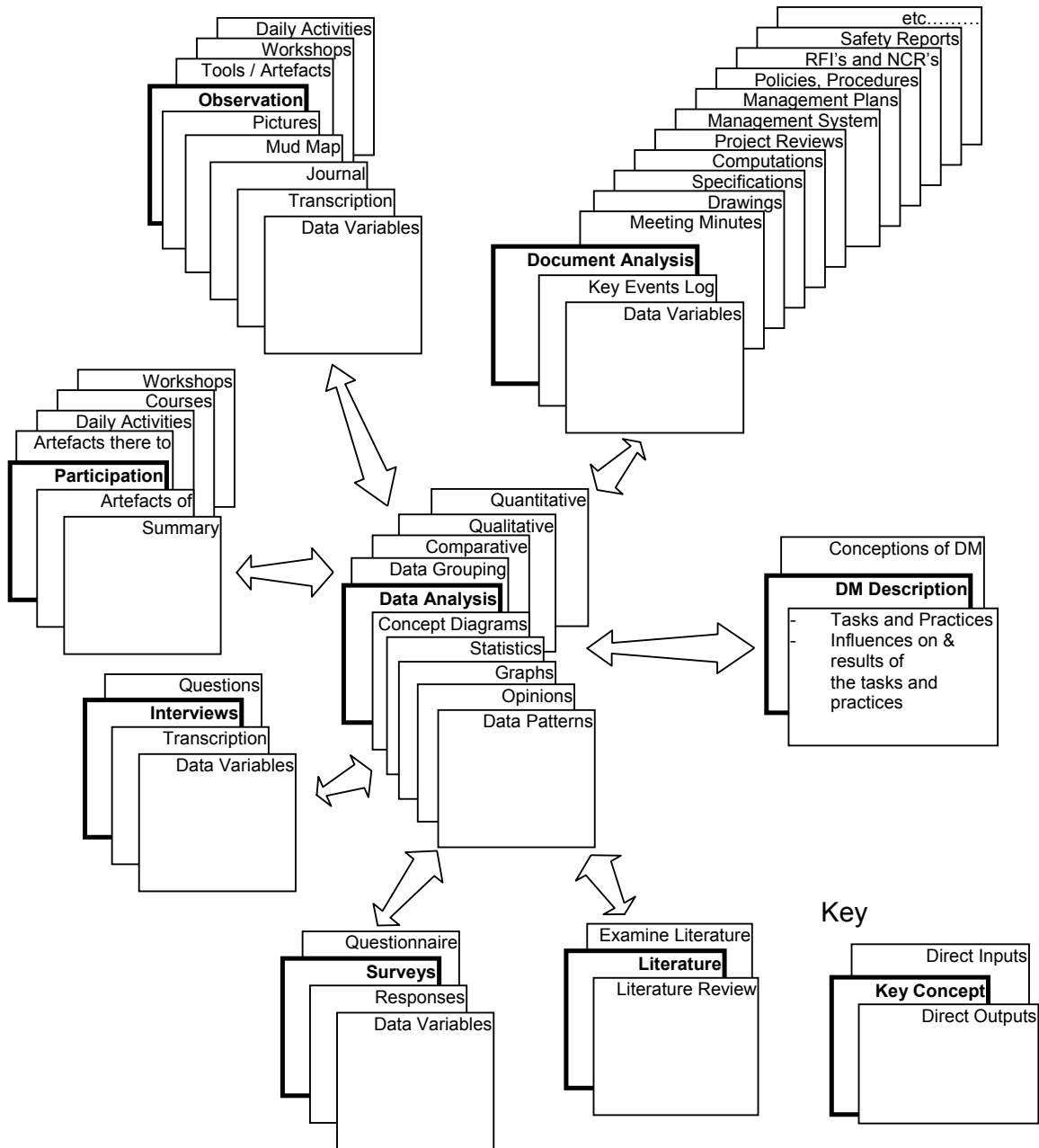


Figure 1 Method used for data collection and analysis

These early results are based on analysis done thus far. Thus far each case study has been analysed separately and qualitative comparisons made between the case studies and case studies on design management before tender stage haven't been completed as yet. It is envisioned that at the end of the data collection period the case studies will be compared with suitable data variables which will positively determine which of the conceptions is most appropriate for design management. This will form the basis of a description of design management which includes the tasks and practices of design management and the influences and results of these tasks and practices.

5.1 Case Studies

Three case studies have been completed, another 2 are underway and a further case study is planned in the future. A brief description of each of these case studies is given below.

A case study has been done comparing two hospital projects in the building sector of the construction industry. These were projects which had been completed before data collection began. Document analysis, interviews with project participants and literature was reviewed in order to determine the design management functions.

A case study has been done on a dam project in the civil sector of the construction industry. This was also a project which had been completed before data collection began. Document analysis, interviews with project participants, and literature was reviewed in order to determine the design management functions on this project.

A case study has been done on a large multi-million dollar tank project combining the civil and process sectors of the construction industry. This was a project that was in the final design stages during data collection. Document analysis, observation, participation, interviews with design management throughout the different stages of the project, and literature was reviewed in order to determine the design management functions on this project.

A case study has begun on a tunnel in the civil sector of the construction industry. This is a project that was in the mid design stages during data collection. Document analysis, observation, participation, interviews with design management and literature will be reviewed in order to determine the design management functions.

A case study has begun on the development of a process plant in the minerals industry. The early stages of design are being investigated during data collection. Document analysis, observation, participation, interviews with design management and literature reviews are planned for this case study.

A future case study is planned on design management in the early stages of a project before the construction company officially secures the project. Document analysis, observation, participation, interviews with design management and literature reviews are also planned for this case study.

5.2 Survey

A survey was distributed to 30 people involved with design management within the construction company. 32 activities were surveyed in order to find out what activities design management currently manage, participate in or are not involved in; what they would like to manage, participate in, or be not involved in; what are considered time consuming activities and what are considered important activities. The functions of design management from these surveys are to be compared to the case studies in order to confirm or dispute the survey results.

6 Analysis and Results

6.1 Design Management Roles

In the three completed case studies different people fulfilled the role of design management. People with various titles often undertook the tasks that design management were responsible for in the three different conceptions. This suggested that meta design, management of design and integration of design and construction were all required in large projects. The titles of people who performed the functions of design management the core tasks they perform is described in order to explain, who was conceptualised as a “meta designer”, who was conceptualised as a “manager” and who was conceptualised as an “integrator of design and construction”.

Thus far the survey and case studies showed that before a construction company put in a bid or tender that design management had a participatory function. More data is required to determine the functions of design management during the before tender stage. Once the company had received the contract for a project they normally required a person, a design manager, design director, operations manager or business development manager to set up systems, which were to be used by design management later on in the project. As the projects approached the design stage the workload exceeded the capacity of this person and further design management personnel were resourced. These personnel consisted of design directors, design managers, senior design engineers or senior architects, design-construction coordinators, design integrity managers and engineering managers. When there wasn't all these personnel the remaining design management personnel took on the roles of the other personnel. Towards the finalisation of the design work only one person, either a senior design engineer, senior architect or design manager was left to deal with the remaining design management issues. Case studies thus far indicate that design management personnel are taken off the project before design finalization and the remaining design management issues left to the construction team and design consultancy.

The people who set up the systems for design management in the case studies conceptually acted as meta designers in that they designed a system in order to get the various stakeholders involved in the design process. These systems enabled the various stakeholders to submit, critique, change and approve parts of the design. These people set up weekly or monthly meetings between relevant stakeholders; co-ordinated the document schedule from the design firm, and determined the subsequent document flow in order for the stakeholders to have design input and approvals to be obtained. Additionally systems which enabled sharing of design documentation and ways to deal with design deviations were devised by these personnel. These people weren't directly responsible for the design or the design team; and they didn't have many design sub-ordinates to manage.

The people who took on the design management functions after the initial set up conceptually fitted the meta designer conception as they used, maintained and continued the development of the system devised by the initial design management personnel, which enabled stakeholders to be co-designers or co-developers. These design management personnel in some ways conceptually functioned as a division of project management in that they partook in activities such as planning, monitoring and control and in that they also calculated document control and design progress metrics. These activities were considered important and time consuming by many respondents in the survey given to design management. However this conception wasn't seen as adequately describing what design management spent most of their time doing. That is communicating with the projects various stakeholders.

Design construction coordinators and design managers dealt with the issues arising from the integrating design and construction conception during a project. However these people did not yet perform all the conceptualised functions that would integrate design and construction. They ensured that design and construction had ample contact. They dealt with issues occurring between design and construction, such as when design clarifications needed to be made. They were faced with issues arising from the traditional ways of working in the construction industry, such as constructors trying to save on material costs rather than using innovative design; constructors making last minute decisions; and designers neglecting construction aspects in their designs. They passed on technical design information to constructors and construction requirements to the design team. They dealt with procurement, estimating and quality control issues, which design impacts upon and they dealt with design for value and value for design issues. They also had a role in integrating stakeholders particularly construction as co-developers and co-designers. When a design-construction coordinator wasn't present other design management personnel took on the issues involved in integrating design and construction.

Design managers, senior design engineers, senior architects, design integrity managers and engineering managers were often used to do the tasks that designers do on smaller projects do, but which inevitably get lost on larger projects. Tasks were done such as: checking that the overall design conformed to the relevant standards; investigating various design options; and involving the various stakeholders in design issues.

Results thus far indicate the following. The personnel responsible for setting up the systems that will be used by design management in a project could be conceptually viewed as “meta designers” who design a system that enables stakeholders to be co-developers or co-designers. The personnel responsible for design management after the systems have been set up could be conceptually viewed as “meta designers” who do the tasks which designers do on smaller projects, but which inevitably get lost in larger projects. The personnel responsible for design and construction coordination could be conceptually viewed as dealing with the issues arising in the “integrators of design and construction” conception.

6.2 Design Management as Integrators of Design and Construction

Design management personnel were observed dealing with many of the issues contained in Column 3 of Table 1. Issues arose such as construction teams not valuing the design process; designers not designing with construction processes in mind; design and construction being considered as separate entities; constructors wanting to save on material rather than use innovative design; individuals making last minute changes to try and make the process more efficient even when design and construction personnel had spent time together determining the most efficient method; and estimates which hadn't taken into account the details of work to be done. The issues developed in the integration of design and construction conception were ongoing issues that required attention in the daily activities of design management personnel.

Overcoming or moderating the issues between design and construction was seen as a necessary role. When these issues were not addressed properly confusion over construction techniques arose, design intent was lost in the final constructed product, unnecessary delays took place and poor project satisfaction was observed. Incorporating constructors as co-developers or co-designers is one way in which integration of design and construction is dealt with.

6.3 Design Management as Managers

The conception of design management as managers was not seen as adequately describing the role of design management in the construction company. Many of the conceptualised “manager’s” tasks that were done, particularly those that were described in the conception design management as a division of project management, were in the context of design management personnel ensuring stakeholders including constructions input into the design.

The conception of design management as managers of design was not seen to adequately describe design management after a project had been secured. Design management personnel at the construction company rarely had many sub-ordinates to manage; they rarely managed a design team or determined design tactics and strategies for design. In addition design managers in a construction company seldom dealt with branding, designing the future of a company or marketing. Further data collection is required in order to determine if this conception describes design management before a project is secured.

The conception of design management as task, flow and value management [28] was not seen as adequately describing the practical role of design management in the construction company. The concept, main principles, methods and practices in the task management view were outside the responsibilities of design management. The concept, main principles, methods and practices of the flow view did not conceptually describe the practices of design management, because the practices were not practiced by design management and elimination of waste was not an overriding principle of design management. The concept, main principles, methods and practices of the value generation view were not seen as adequately describing design management as it stands, because design management were taking into account several stakeholders requirements and weren’t doing the suggested methods and practices by themselves. In line with Riley and Clare-Brown [31] this description would require substantial modification to be used to describe the practice of design management in the construction company researched.

6.4 Design Management as Meta Designers

Design management personnel were observed designing and maintaining a system, which incorporated stakeholders as co-developers or co-designers. They were also observed doing tasks which designers are responsible for in smaller projects that inevitably get lost in larger projects. Early results indicate that this conception of design management better describes the practical tasks of design management than the design management as manager conception.

Two main functions of design management personnel cited in company documents was ensuring stakeholders understood design developments or design changes and maintaining the design intent. Utilizing stakeholders as co-developers or co-designers ensured that they were up to date with the design developments and that the design intent was maintained.

The tasks within the meta designer conception were observed in the case studies as being required in the construction industry. When the tasks of incorporating stakeholders as co-developers or co-designers were neglected a resultant delay or hold-up became apparent. Such delays included approvals taking a longer time than expected, because a stakeholder’s issues were not addressed, document delays because designers didn’t understand stakeholder inquiries and misunderstandings occurring between stakeholders, which caused design errors and resultant rework.

7 Conclusion

A conception of design management, which resembles design management practices in a construction company, is emerging along with a detailed description of those practices. Early results indicate that design management in the construction company after a tender has been secured can be better conceived as “meta designers” rather than as “managers” and that they also deal with the issues described in the conception of design management as integrators of design and construction. The design management personnel were responsible for designing a system, which made the stakeholders the co-developers or co-designers; they did the tasks that designers are responsible for in smaller projects, but which inevitably get lost in larger projects; and they dealt with issues arising from the integration of design and construction conception. This information can provide a foundation for better co-ordinated design and construction in complex one-off engineering projects.

References

- [1] Brown, D. C., Ashleigh, M. J., Riley, M. J., and Shaw, R. D., "New Project Procurement Process", *Journal of Management in Engineering*, 17(4), 2001, P. 192-201.
- [2] Gray, C., "Faster, Better Value Construction. A Best Practice Guide to Construction Management", The University of Reading, Reading, 1996.
- [3] Law, B. J., "A Preconstruction Foundation for Design-Build Success", The 48th Annual Meeting of AACE International: 2004 AACE International Transactions, AACE International 2004, Morgantown, 2004, P. PM181-PM183.
- [4] Crawley, D. B., "Civil Engineering Design Management: Teaching by Project", University of Adelaide Department of Civil Engineering, Adelaide, 1985.
- [5] Gillette, H. P. and Dana, R. T., "Cost Keeping and Management Engineering: A Treatise for Engineers, Contractors and Superintendents Engaged in the Management of Engineering Construction", The Myron C. Clark Publishing Co., New York, Chicago, 1909.
- [6] Hughes, W. P., "An Analysis of the JCT Design & Build Contract", University of Reading, Reading, 1992.
- [7] Anumba, C. J. and Evbuomwan, N. F. O., "Concurrent Engineering in Design-Build Projects", *Construction Management & Economics*, 15(3), 1997, P. 271-282.
- [8] Rosenfeld, Y. and Geltner, D., "Cost-Plus and Incentive Contracting: Some False Benefits and Inherent Drawbacks", *Construction Management & Economics*, 9(5), 1991, P. 481-493.
- [9] Puddicombe, M. S., "Designers and Contractors: Impediments to Integration", *Journal of Construction Engineering & Management*, 123(3), 1997, P. 245-252.
- [10] Kagioglou, M., Cooper, R., Aouad, G., and Sexton, M., "Rethinking Construction: The Generic Design and Construction Process Protocol", *Engineering Construction & Architectural Management* (Blackwell Publishing Limited), 7(2), 2000, P. 141-154.
- [11] Kenna, I., "Why do we say "Estimate" when we mean "Exact"?" *Project Management Australia Conference 2004*, Melbourne, Australia, 2004, P. 2.
- [12] Construction Industry Forum, "The Declining Standard of Documentation in the Building and Construction Industry - Report on Possible Causes and Solutions - Outputs from Construction Industry Forum", *Engineers Australia*, 2004.
- [13] Tilley, P. A., "Causes, Effects and Indicators of Design and Documentation Deficiency", *The International Conference on Construction Industry Development*, Singapore (9-11 Dec), 2 2, Singapore, 1997, P. 388-395.

- [14] Akintoye, A., "Just-in-Time Application and Implementation for Building Material Management", *Construction Management & Economics*, 13(2), 1995, P. 105-113.
- [15] Pheng, L. S. and Hut, M. S., "The Application of JIT Philosophy to Construction: A Case Study in Site Layout", *Construction Management & Economics*, 17(5), 1999, P. 657-669.
- [16] Ballard, G., "Managing Work Flow on Design Projects: A Case Study", *Engineering Construction & Architectural Management (Blackwell Publishing Limited)*, 9(3), 2002, P. 284-292.
- [17] Guindon, R., "Cognitive Science and Its Applications for Human-Computer Interaction", Lawrence Erlbaum Associates, Hillsdale, N.J., London, 1988.
- [18] Moody, J. A., Chapman, Voorhees, and Bahill, "Metrics and Case Studies for Evaluating Engineering Designs", Prentice Hall PTR, Upper Saddle River, N.J., 1997.
- [19] Johnston, S., Gostelow, P., and Jones, E., "Engineering and Society: An Australian Perspective", Addison Wesley, South Melbourne, 1999.
- [20] Cross, N., "Engineering Design Methods: Strategies for Product Design", Wiley, Chichester, New York, 2000.
- [21] Dorst, K., "Understanding Design", BIS, Airlift, Amsterdam Enfield, 2003.
- [22] Ballard, G. and Koskela, L., "On the Agenda of Design Management Research", 6th Annual Conference of the International Group for Lean Construction, Guarujá, Sao Paulo, Brazil, 1998, P. 13.
- [23] Gray, C. and Hughes, W., "Building Design Management", Butterworth-Heinemann, Oxford, 2001.
- [24] Hales, C., "Managing Engineering Design", Longman Scientific, London, 1993.
- [25] Cooper, R. D. and Press, M., "The Design Agenda: A Guide to Successful Design Management", Wiley, Chichester, England, New York, 1995.
- [26] Koskela, L., "An Exploration Towards a Production Theory and Its Application to Construction", University of Technology, Helsinki, 2000.
- [27] Koskela, L. and Howell, G., "The Underlying Theory of Project Management is Obsolete", PMI Research Conference 2002, Project Management Institute, 2002, P. 16.
- [28] Koskela, L., Huovila, P., and Leinonen, J., "Design Management in Building Construction: From Theory to Practice", *Journal of Construction Research*, 3(1), 2002, P. 1-16.
- [29] Fischer, G., Giaccardi, E., Ye, Y., Sutcliffe, A. G., and Mehandjiev, N., "Meta-Design: A Manifesto for End-User Development", *Communications of the ACM*, 47(9), 2004, P. 33-38.
- [30] Yin, R. K., "Case Study Research - Design and Methods - Third Edition", Sage Publications, Thousand Oaks, London, New Delhi, 2003.
- [31] Riley, M. J. and Clare-Brown, D., "Comparison of Cultures in Construction and Manufacturing Industries", *Journal of Management in Engineering*, 17(3), 2001, P. 149-158.

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