HUMANISTIC AND SCIENTIFIC KNOWLEDGE MANAGEMENT: A COMPARISON OF DESIGN PRACTICE BETWEEN ARCHITECTS AND ENGINEERS

Peter Raisbeck[1] and Llewellyn C.M. Tang[2]
[1] *Faculty of Architecture, Building and Planning, University of Melbourne, Victoria 3010, Australia*
[2] *School of Construction Management and Engineering, University of Reading, RG6 6AW, UK*

It has been suggested in more recent research findings that architectural and engineering consultancies can be characterised as knowledge intensive professional firms. Besides, the extensive use of Information and Communication Technologies (ICTs) has both positive and negative impacts on these knowledge workers. In this study, the management of design knowledge will be strictly related to the activities of the architects and engineering consultants and is conceived of here as unique, and often one off activity or process which does not end once the initial design has been created. Given this, the aim of this study is to understand, identify and highlight the importance of how design knowledge is created, captured and then managed in architectural and engineering consultants in a small office in the UK and Australia. The research questions are: once design knowledge is created how is it then managed? Is this knowledge always implicit? Does it become embedded in structures and systems? How do these firms manage it with the help of ICT? Based on two case studies in small offices; one in an small architectural firm in Australia and the other in an large engineering firm in the UK., a high level knowledge-knower structure is constructed by mapping the design knowledge in relation to each practice. From this results and findings, a preliminary framework of humanistic and scientific knowledge management in these design-intensive firms is then finally proposed that could improve the productivity of these knowledge workers in terms of reusing personal and codified knowledge.

Keywords: architecture, design practice, engineering, knowledge management.

INTRODUCTION

Professional service firms have a significant role in the property and construction industry. These firms tend to be much smaller than their counterparts in either manufacturing or non project based organisations. Despite their size these firms are central to the integration of design with construction processes in the delivery of building projects. Often these firms, such as architects and engineers, will create various designs which integrate together the different systems which comprise a project. Often these firms will then monitor, co-ordinate and manage their initial design as construction proceeds with other professionals, contractors and sub-contractors. The design engineer or architect may gather in data and information from clients, regulatory authorities, user groups, or other sub-consultants. This data and information may even be gathered from the physical environment itself in order to

[1] raisbeck@unimelb.edu.au
[2] L.tang@reading.ac.uk

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create design knowledge. In the initial stages of a project this design knowledge may include, identifying design problems, adapting existing design knowledge adapting design or generating new design solutions. This may involve creating design knowledge which takes into account issues concerned with cost or constructability. Once this initial design knowledge is created other activities then take place including: monitoring the design against aesthetic or cost issues as it is constructed; solving subsidiary problems in order to retain design integrity and communicating design knowledge with other members of the project team. Understanding how the design knowledge from these processes is important because the creation and management of this design knowledge enables these firms to become "agents of innovation" (RICS, 2006, p.5). The above context suggests that professional service firms create a great deal of design knowledge that must then be managed. Understanding how different types of professional service firms working in different contexts and locations are an important first step in pursing this type of research. This is because a comparison between seemingly disparate knowledge professionals will highlight the full range of issues that may be involved in the management of design knowledge within knowledge intensive professional firms.

Aim and objectives: Given the above context our aim in this study was to understand how design knowledge is managed in engineering and architectural practices under a different knowledge and information transformation models (KITM) developed by Tang *et al.* (2008b). As construction Small and Medium Enterprises (SMEs) are still in the early stages of understanding how to knowledge capture in order to sustain competitiveness (Suresh and Egbu, 2007). Information sharing, retrieval strategy are bounded by law and also by a number of physical boundaries such as the size of firm and the number of employees (Tang *et al.*, 2008a). Also in line with Lu and Sexton's characterisation of knowledge intensive firm (Lu and Sexton, 2006) our scope of analysis and approach was to conduct semi-structured interviews in two small offices in two companies: one is a large engineering consultant based in the UK and the other is a small architectural consultant based in Australia. Comparative analysis on their KITMs is drawn to answer the above research questions and a knowledge-knower structure is finally provided for further research. The research questions of this study are therefore:

- Once design knowledge is created how is it then managed?
- Is this knowledge always implicit?
- Does it become embedded in structures and systems?
- How do these firms manage it with the help of ICT?

LITERATURE REVIEW

A number of approaches have been taken in the past to understanding design in the context of Knowledge Management (KM). A core issue in the construction industry is the need for different professionals to exchange information and knowledge during the construction process. There are many definitions on data, information and knowledge reported in the literature. Data can be defined as “facts, statistics that can, frequently, be analysed to derive information”. Information is “the descriptive content of a message which allows a change in through interpretation”. Knowledge is a cumulative understanding of the information and data in the specific context of an application (British Standards Institution, 2003). These refer to a DIK hierarchy as shown in figure 1. Tang *et al.* (2007, 2008b) defined that the hierarchy consists of three stages in two main levels: recorded and personal (See figure 1). In analogue to the "Iceberg

model" defined by Quintus (2000) that illustrates knowledge as explicit, implicit and tacit. Tang *et al.* (2007, 2008b) defined "knowledge can be explicit (recorded or codified in some way), implicit (in the mind) or even tacit (cannot be recorded and codified in any format). Explicit knowledge can be stored as information".

Hicks *et al.* (2002) studied these in the domain of engineering design where “data is considered to be structured and represent a measure such as quantity; and information is defined in two classes: formal information (provides a specific, structured context and measure) and informal information (encompassing unstructured); and knowledge is inferred from information through a knowledge creation process”. Indeed, the creation of design knowledge generated through knowledge exchange or interaction between different disciplines may take place though a number of different means. As (Gann and Salter, 2002) observed in a component analysis of design ideas sources ranged from talking to colleagues, individual work, talking to clients, Techniques used for solving ideas included; face to face conversations, sketching on paper, using analytical engineering skills, working in collaboration or alone and scouting for new ideas on the internet. Besides, the understanding between stakeholders such as architects and engineers may vary from time to time throughout the project.

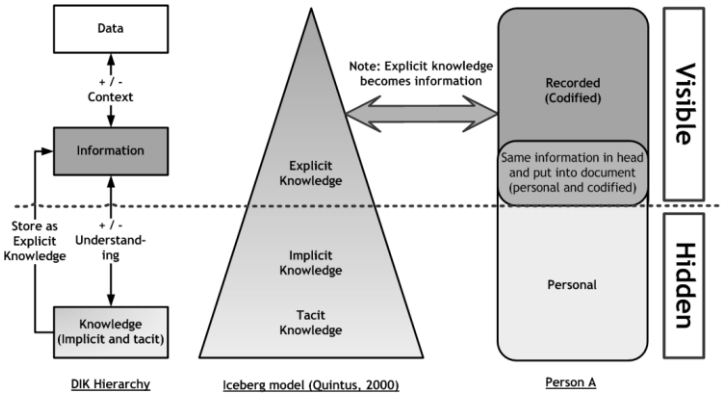

Figure 1: Codified and personal knowledge (Tang et al., 2007, 2008b)

As identified by a number of researchers, differences in the way that engineers and architects think and communicate have been well documented. In the literature these characterisations have taken on different guises. Engineers are generally seen as professionals who create design knowledge in a linear and sequential way whereas architects are often described as creating design knowledge in more generative and chaotic fashion. Maton (2007) explained and further demonstrated the difference between humanist and scientific culture using a knowledge-knower structure. In humanist culture, a knowledge structure is longitudinal while a knower structure is hierarchal and this is vice versa in scientific culture. This has been described as the difference between path dependent and path creating modes of designing (Boland and Collopy, 2004). Their study defined path creating design as "developing a new, generative and reinforcing set of relationships among elements in a socio-economic system is path creating activity" (Boland and Collopy, 2004, p.274). Path creating design "breaks from the expectations of the familiar 'logical' way of proceeding." Path dependent design on the other hand is a "dominant pattern of problem solving because self-reinforcing relationships of expectations, demand, production costs, logistics and technologies will form" and also: "path dependence leads to a sense of economy and efficiency in the reinforced relationship that dominate our understanding of a situation, but often at the expense of the effectiveness of unexplored alternative solutions" (Boland and Collopy, 2004, p.274). Some knowledge management

practitioners have attempted to overcome this disciplinary schism by pursuing integrated and multi-disciplinary collaboration. For example, the "Integral Design" project in Holland aimed to raise awareness amongst professionals of different disciplines in relation to design knowledge and its exchange of the different positions. As stated the aim of this approach is to "reach true synergy between all different design disciplines that are essential or necessary for completeness of design" (Zeiler *et al.*, 2008, p. 71).

In addition to the above, another recognised area of research related to architectural, engineering and knowledge management relates to the use of ICT technologies to capture and retain this knowledge. These studies have often focused on how various ICT tools such as intranets, project websites or document management tools have helped to manage knowledge and information within a firm. For example, Otter has examined the use of project websites to share knowledge between members of architectural design teams (Otter, 2007). Otter (2007) argues that "systems for sharing of knowledge in such teams are important for collective understanding of a design during its development, to derive insight and overview on progress of design and to prevent misunderstandings and failures". Otter also points out that a critical issue in this area of KM research is the fact that design knowledge is often implicitly stored in designer's heads and explicitly stored as both physical models, paper documents and electronic drawings, models and images. This highlights the importance of understanding the systems which capture knowledge in design firms as the extensive use of Information and ICTs has both positive and negative impacts on these different knowledge workers (architects and engineers).

CASE STUDY BACKGROUND

This research identified current approaches to knowledge management and design practice in an architectural (Arch-Con) and engineering consultant (Eng-Con). Table 1 details the two case studies in their small offices, including the history, nature of products and services provided and scale of offices being studied and number of employees as a whole.

Two exploratory case studies were conducted in the UK and in Australia examining three perspectives including director, project management (from an architect or engineer) and ICT. Interviews can be highly structured, semi-structured or unstructured (Easter-Smith, 2008). This exploratory study adopted a semi-structured approach. A total of six semi-structured interviews (three each) were conducted with a modified template of 12 questions from Tang *et al.* (2008b) covering:

- Demographics: including questions about the background and position of the interviewee;
- Information sources: including questions about the types of information the interviewee deals with and information systems the interviewee uses on an everyday basis;
- Knowledge and information management approaches: including questions related to knowledge sharing, management, and transferring from the interviewee’s perspective;
- Final considerations: the biggest challenge in knowledge and information management the interviewee is facing.

Table 1: Company background of the case study

Case Study	Arch-Con	Eng-Con
History	Established 8 years ago	Established over 30 years ago
Nature of Products and Services	The practice has been involved in residential, retail, commercial and urban design projects. The largest project currently in the office is a $AUD 100M urban design project for a harbor esplanade. In conjunction with structural engineers and other consultants the firm has been involved in the design of a number of roads and bridges including pedestrian footbridges over highways.	An international company produces engineering design, project management and consulting services in Structural Engineering, Building Services and Site Infrastructure. One of the future challenging projects will be part of the consortium appointed to design the Olympic Park for the London 2012 Olympic and also to provide consulting to the major stadiums.
Scale of Offices in this Study and Employees Number as a Whole	Since that time it has grow rapidly and it currently has 3 directors and employs up to 15 staff.	Has both national and international offices employing over 1,700 people. The office studied in this paper has 3 directors and 50 staff.

RESULTS AND ANALYSIS OF THE CASE STUDIES

Overall KM practice

Regarding the overall KM practice, both offices in these two companies have the similarity and adopted a similar model demonstrated by Tang *et al.* (2008a, 2008b). Their Hardware-Software-Critical-ware (H-S-C) model suggested the KM practice is a combination of software (e.g. intranets and extranets), hardware (e.g. database and personal PCs) and critical-ware (means people e.g. individuals as knowledge brokers mostly such as knowledge brokers, knowledge mangers, document controllers, librarians or a group of people in communities of practice, (CoP) no matter what the size of the company is.

Arch-Con: The Arch-Con focuses more on hardware and software. In terms of hardware, the Arch-Con runs 15 personal computers operating on a dedicated server with a tape backup system. Along with this there are also a number of communication tools which the director in the company argued as "being increasingly more important for email communication." These devices include i-phones and laptops. Other important peripheral devices are digital projectors and multi-page scanners used to digitally archive documents came into the office. In terms of software, the office uses Skype and had attempted using Wikis but these had not been that successful. For computer aided design the office uses both 2D and 3D software tools. The office appears to use standard office information management systems to manage projects once they are out of the design phase. This includes the use of intranets and shared servers for the exchange of knowledge with clients and consultants. In addition, the office has a license to use a software product designed for the management of architectural practices which employs a database for the management of contract administration documents and invoicing. The office does have an office manual which guides the strict archiving and naming of information and data files and it is enforced by certain individuals such as the directors or project managers.

Eng-Con: The Eng-Con focuses more on software and critical-ware. The highlight is the well-developed resulting Intranet site since 2000 which information sharing; in particular it pushes and backs up information to support several communities of

experts. It has lots of technical information (e.g. an online building services design guide). There are people's profile (names, pictures, contact details) on the Intranet to link people. This provides a single point of reference for the company to managing engineering design projects. There are formal ways to manage and train people in interface with the ICTs. In terms of critical-ware, the firm has several knowledge brokers work closely to deliver the best KM practice. Every office has a small library and the biggest one is managed by a librarian who is responsible to deal with all the technical information. She also oversees the practice of how they actually go about archiving in major offices. The project team especially the three major Knowledge Managers who are responsible for different disciplines should make sure that crucial information is placed on both the intranets and extranets. The Collaboration Tool Champion studies protocol document management, information management and sets up procedures to push KM within the project life cycle such as the use of Microsoft SharePoint and project forums recently.

Personalisation and Codification

Anumba *et al.* (2005) suggested that construction professionals are based on a balance between explicit and tacit knowledge throughout the project life cycle and they are interchangeable by different kinds of codification methods. By the theory of knowledge creation mechanism (Nonaka and Takeuchi, 1995) and the personalisation and codification model (Tang *et al.*, 2007, 2008b), there are four ways of transferring implicit (refer to tacit in the original model) and explicit knowledge, namely: by "Socialisation", implicit knowledge of an individual can be transferred to implicit knowledge of another individual (e.g. webcams, meetings) and by "Internalisation", explicit knowledge is transferred and stored as implicit knowledge through training and databases. These two activities show that if design knowledge is always implicit, by "Externalisation", implicit knowledge of an individual can be transferred to explicit knowledge by for example expert systems and CoPs. This activity shows once design knowledge is created how it is then managed, and finally by "Combination", explicit knowledge is transferred using company intranets, software and personal PCs and it shows the way that the firm manages it with the help of ICTs and hence prove if it becomes embedded in structures and systems. The following sections study the differences on these between two firms under different perspectives.

Methods of Codification in Arch-Con

(a) Internalisation-driven externalisation: The Ach-Con director said once information has been gathered for a given design project the company's directors and staff then produce drawings, sketches, physical models, 2D and 3D digital diagrams and models. In the early stages of a project, relevant diagrams, images, texts were gathered and used as reference sources as the design proceeds. This reference information in the form of "visual clues" would be sourced or "drawn down" from the web.

(b) Combination-driven externalisation: The director said information of existing conditions, online reference information and architectural precedents were then aggregated, often in hard copy form available for other staff in the office. It was observed that this aggregated information quite often would be more specific to the project and lead to new at hand as compared to it was felt that by using the online sources in this fashion that this sometimes led to "entirely new or unexpected areas" of design knowledge and this was a better method than referring to a book dedicated to particular area of architectural design. The project architect affirmed that in creating design knowledge the directors maintain design control but they were "open and eager

to draw on the resources of the staff" and encourage a collaborative approach. The project architect explained that the use of independent research in the office and the visualisation software was very helpful in helping to solve design problems once a project had started. In addition, the design reports are a primary means by which design knowledge is disseminated in the office. Once a range of hand sketches produced by the directors or director responsible for the project various ideas or concepts were selected for further development. For example a plan hand sketch may be imported into the software package and then traced over in this in order to continue development. In this process a sketch is handed down from a director and then this is often denoted with a number of "tags" with a reference to one of the practices design reports. Interim 3D renders and line drawings are then produced and these are printed to facilitate further iterations.

(c) Socialisation and combination-driven externalisation: The Arch-Con ICT people said that one way in which knowledge is made explicit and codified in the office is through the use of an office manual. This document ensures that staff members are up to date with archiving. For example, on the firm's largest project there are regular design meetings where everyone can come together to discuss and produce solutions to particular design problems. It was observed that there was a "very open and collaborative approach to producing design knowledge in the office". TheArch-Con director talked about the practices weekly forums. The Friday night talks and saw their importance in the fact that they exposed various office members to different ways of designing. For example the talks had included design talks from people outside of the architectural discipline including artists and industrial designers.

Methods of Codification in Eng-Con

(a) Combination-driven socialisation: The Eng-Con director said the infrastructure of the Intranet is very good, however it needs to be restructured. For example, the staff profile needs to be upgraded. Also, as it is multi disciplinary, the email distribution list cannot be updated automatically and is done manually with constant tracking by the Knowledge Manager. Moreover, no knowledge transfer is done and there is a lack of externalisation through the Intranet. It stores data and information only and what is important is the context. As people find knowledge, so the links between people are much more important than capturing and storing knowledge electronically. The Eng-Con director mentioned that the company is a collective organisation and people tend to share knowledge and focus more on socialisation. There are two Knowledge Managers using meetings or involving people who have been involved in past projects in start up or review process in new project to share experiences. Collaborative type meetings such as start up meetings, project review meetings and workshops provide a platform to learn from experience and to transfer knowledge successfully.

(b) Socialisation-driven externalisation: The Eng-Con engineer said information sources are mainly email and conversation. The intranet is a channel for people to find the right people to talk to. There is well-established technical and procedural information on the Intranet. He preferred to have a short conversation rather than sending email to transfer knowledge. He assumed that information outside the company like software purchases or external technical guidance documents are technically correct such as British Standards a lot. He said project team had a review in each stage to capture the learning in reports; the crucial part was to share what was happening. The ICTs people said that knowledge retention is a cultural thing, not a technology thing. People cannot know how to use Google without knowing what to put in and the organisation cannot just capture information without capturing implicit

knowledge. They need time to look forward to work out how to help people find expertise in the office.

Overall KM challenges

The Arch-Con office currently has a structured KM system. It is clear that the firm's expertise lies in generating hierarchical design knowledge and the managing this knowledge (personalisation) by making it explicit (codification) through the dissemination amongst the office of the conceptual design reference reports. The collaborative creation of design knowledge is clearly where the office has and is trying to gain competitive advantage over its competitors. This process is clearly what Brenner and Tushman (2003) would call exploitative knowledge. It was observed that the firm focuses on software and hardware, there is no overlay, system or ontology to search this archive of information compared to the well-developed Intranet in Eng-Con. The overall KM challenge in Eng-Con is how to work through the right people with the support of ICTs. ICTs always develop while lots of codified and personal information in engineering design is semi-structured and longitudinal. There is a challenge for the firm to make them compatible with each other; there is rarely a way or framework Knowledge Brokers to bridge the gap and helping engineers to work in a smart way. In the future, many organisations will become more global, standardised and systematic. It is important to allow the knowledge workers to talk together and to have a consensus about different knowledge management issues in order to put theory into practice.

FUTURE WORKS

In the knowledge-knower structure we noted earlier Maton (2007) explained and further demonstrated the difference between humanist and scientific cultures. In humanist culture, a knowledge structure is longitudinal while a knower structure is hierarchal and this is vice versa in scientific culture (See figure 2).

Figure 2 adopted the KM models of Quintus (2000) and Tang *et al.* (2007, 2008b) together with Maton (2007)'s knowledge and knower structures under humanist and scientific cultures. In this study, the Arch-Con focuses more on hardware and software, which is a knowledge structure. The structure between personalisation and codification is more hierarchical as reflected by the architects not the engineers. The culture is scientific in nature and the epistemic relation increases among architects as long as this structure is sustained. On the other hand, the Eng-Con focuses more on software and critical-ware, in other words a knower structure. The culture is humanist in nature and the social relation increases among the engineers as time goes by. However, the international context of the study needs to be highlighted as the discrepancy in culture between two countries may play a major role on shifting the nature in the developed framework. Further, instead of comparing two small offices, a bigger scale of comparisons on project and corporate levels shall be conducted comparing companies of similar sizes. Based on this framework, the consultants know the types of knowledge management that they are currently adopting and they can decide to change the balance between hardware, software and critical-ware if the current structure does not maximise knowledge, sharing and capture.

CONCLUSIONS

This study compares knowledge management and design practice in two small offices in two construction SMEs; one is a small architectural consultant (Arch-Con) in Australia while the other one is a medium-sized engineering consultant in the UK. In

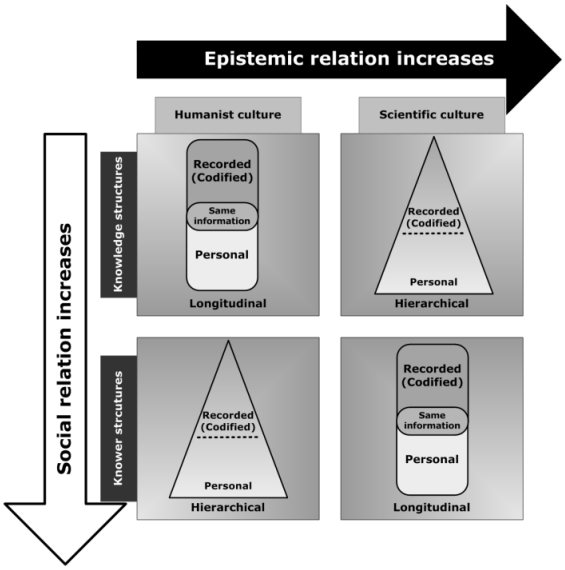

Figure 2: A humanist and scientific knowledge management framework

particular, it addresses once design knowledge is created how it is then managed by externalisation with the help of ICTs if possible, otherwise, should it be located implicitly in people's heads or embedded in structures and systems. The results of the comparison showed that the Arch-Con focuses more on hardware and software. Implicit knowledge among the knowledge workers (mostly architects) is more hierarchical while that in employees (mostly engineers) in Eng-Con is more longitudinal. Besides, in Arch-Con all three perspectives (Director, Project architect, IT) reported that they use various externalisation methods to codify implicit knowledge. In the case of Eng-Con, all the perspectives reported that the externalisation they preferred is more socialisation-driven. Finally, a preliminary framework of humanistic and scientific knowledge management in these design-intensive firms is then finally proposed. The validation and evaluation of this framework will be proposed as future works that could possibly improve the productivity of these knowledge workers in terms of reusing personal and codified knowledge. The effectiveness of this approach could be reflected by an empirical approach that measures the productivity of these two types of workers.

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