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Information management/sharing problems during the inspection stage of construction: A case study in Australia

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Abstract
Information is one of the vital assets to the organizations irrespective of its industries. If information is utilized effectively in the construction process, it will allow users to plan, operate, and make decisions to maximize benefits. This paper reports the information management practice problems among stakeholders during the inspection stage in a building construction project in an Australia urban-based university. The study explores how specific information was generated, recorded, disseminated, used and stored during the inspection stage in the construction process through the roles of architects and builders. Data was collected over 14 week period through document analysis, shadowing, observations, photography, and one-on-one interviews with builders and architects involved in the project. The research shows that information was recorded, stored and reused through both personal and enterprise information management; that stakeholder's tacit knowledge played an important role affecting how the information was generated, stored and reused; and that the complexity of information and dynamic nature of procurement method used in this project had an impact on how information was utilized during the inspection process. The paper concludes with suggested methods to record unstructured information generated on-site and better ways to utilize and reuse information in construction.

Keywords
Information Sharing, Information management, Construction Defects Inspection

1. Introduction

Information is one of the most important assets that an organizations in all industries need to acquire and manage. Utilized correctly, information may allow an organization, irrespective of its domain, to communicate, operate, plan, and make decisions that would ultimately be beneficial to itself, their clients and other stakeholders who interact with them (Buchanan & Gibb 2008; Kousky & Cooke 2012). This

includes multiple stakeholders industry such an Architecture, Engineering and Construction (AEC) industry. Information management in the AEC industry been reported in previous studies (Al Nahyan et al. 2012; Lucas, Bulbul & Thabet 2013; Nuesse, Limbachiya & Ellis 2012). These studies involved the exploration of information management through the use of technologies within the different stages of a construction project (Hassan Ibrahim 2013; Kang, O'Brien & Mulva 2013). However, there have been limited studies that have dealt directly with the defects inspection stage from the perspective of information sharing.

The construction process is complex and can be separated into a numbers of stages which depend on types of procurement method. Stakeholders who get involved in each stage are also different (Cheung, Wong & Lam 2012; Ricketts 2001). The detail about types of procurement methods and overall construction processes are outside scope of this paper. This research focuses on information sharing during the defect inspection stage in the construction process in a case study of a major complex building in Australia. Defect inspection in construction is the process where the constructed building is evaluated against various reference standards, including project-specific and standardized designs and construction specification (Boukamp & Akinci 2007). The purpose of defect inspection is to ensure that the constructed building can perform and accommodate all requirements and designs and comply with all building codes and regulations required. If the constructed building deviates from the stated specifications, relevant stakeholders have to rectify until it meets the levels agreed with the client. Stakeholders who perform the defect inspection include sub-contractors, contractors, project managers, engineers and architects and can occur in iteratively (Sawhney et al. 2005).

This study evaluates the information management and sharing practices in a team of stakeholders. These included architects, builders, contractors and project manager as they cycled through the defects inspection stage of a complex construction project of a purpose-built educational building for an Australian university. The project took a little over four years from conceptual design stage until opening to staff and students one hundred and eight days ahead of schedule. During this time stakeholders involved in the construction of the building were required to manage and share copiousness amounts of information which manifested in a multitude of formats. Through the lens of an Information Management perspective, this particular study examined the Information Management (IM) practices of the stakeholders as they completed the defects inspections for this complex construction project.

2. Research context

Information management refers to all activities required of managing information that needed to carry out the tasks (Becerik 2004). These activities include generation, retrieval, codification and analysis of information (Cuenca, Boza & Ortiz 2011). The information sharing process can be seen as one in which two or more entities are involved in the exchange of tacit and explicit information (Ford & Staples 2010). Utilized efficiently, it can be leveraged to create competitive advantage for any organization (Bryant 2005; Porter 1993). It incorporates a mixture of existing and newly generated information and generally happens whilst employees or experts within a specific knowledge domain collaborate with each other (Lilleoere & Hansen 2011; Singh, Dong & Gero 2012).

In a perfect world, information sharing should be an efficient process in which all entities involved possess and comprehend the information required to complete their goals. However, there are many factors that may affect this, and ultimately lead to inefficient information sharing. Reilly and Sharkey (2010) mentioned that an individual’s ability to interpret received information, utilize, and turn it into meaningful action is one such factor. Without the understanding of the information presented, the individual could be seen as less effective in the information sharing process.

Nonaka (1994) mentions that to share information and tacit knowledge in an organization as well as inter-organizationally requires social interactions between individuals through human activities. These interaction groups can be drawn from within an organization or amongst individuals formed outside the organization. Nonaka then goes on to suggest that in order for information sharing to be a success, there has to be trust among individuals in the group, and the existence of a common perspective that each individual has towards the group and towards dialog or individual communications (Cumbie & Sankar 2012; Nonaka 1994).

Formats of the shared information also pay an important role in information sharing in the construction process (Rezgui, Hopfe & Vorakulpipat 2010; Vanlande, Nicolle & Cruz 2008). These included client's requirements, holistic visualized data such as architectural designs, technical information such as engineering designs, products and materials specifications and communication information. Relevant stakeholders in the construction process have to bring about all sorts of information from other stakeholders and integrate them into a constructed building (Chiu & Russell 2011).

In construction projects, the way people categorize documents and manage their information is highly personalized. This is most often linked to their experiences and the specific domain knowledge that they possess. The combination of these two factors influences the way they make use of information and as previous studies have demonstrated, this changes over time as well as from project-to-project (Arnorsson 2012; Ilozor & Kelly 2012).

3. Research methodology

In order to select the most appropriate framework to apply, an understanding of the methods used in this study must first be considered. The study primarily involved the investigators observing the stakeholders as they completed the defects inspections for a purposely-built academic building. During the 37 on-site observations which occurred between March to June 2013, investigators recorded details notes in relation to information sharing process amongst the stakeholders and then trying to make sense of what was happening. Due to the nature of the case study and the methods utilized, an interpretative framework was adopted. Denzin (1994) describes interpretive research as one where the "fieldworkers can neither make sense or understand what has been learnt until they sit down and write interpretive text, telling the story first to themselves then to significant others and then to the public" (Denzin 1994, p. 502). Walsham (1995) also states that interpretive research is a method in which human actors construct our knowledge of reality, and that where value-free data cannot be obtained. Walsham suggested that it is the investigator that makes use of their preconceptions in order to guide the process of inquiry, and that the interactions between the investigator and human subjects change the perceptions of both (Walsham 1995).

This is a case study research of a single building construction project. Case study research is one in which it 'investigates a contemporary phenomena within its real-life context, especially when the boundaries between phenomena and context are not clearly evident' (Yin 1994, p. 13). Stake (1978, 1995) and Eisenhardt (1989) also indicate that a case study is a good technique to use whilst studying social phenomena within a single setting. It can also assist the researchers in answering the 'how' and 'why' questions in situations that involves social behavior through exploratory, descriptive or explanatory research, which in this study the question is how stakeholders share information during the defect inspection process?

3.1 Research Setting

The defects inspection team comprised six stakeholders of whom there were three architects, from an Architecture firm, two builders from a Main Contractor firm and a project manager. Due to the research ethics the name of stakeholders' firm cannot be disclosed. Although there were six stakeholders

identified, during the on-site defects inspections, there would generally only be a core team of four present (detail in Table 1), depending on their availability. The project manager and the principal architect, although apart of the team, were not often present (this is because he had executive commitments in the Architect firm), and if so, he was there to solve any major issues that had arisen. They were often engaged in other aspects of the construction project and left after the issue was resolved.

Table 1 Research participant's details

Stakeholders	Role and characteristics
Architect A	Architect A is a very experienced "site architect" who has been in the industry for over 30 years. His primary role was to be onsite and work through all the defects with the builders. He also needed to make sure that the information from the drawings and other architects were relayed correctly back to the builders and that finished product met the architectural specifications.
Architect B	Architect B could be classified as a "documentation architect" his primary role was to document the specifications for the building. Architect B was trained in Germany and has been working in the industry for over 10 years. During this project Architect B assumed Architect A's role for 6 weeks during the inspections" whilst Architect A was overseas on leave and continued to working on the defects inspection stage till it was completed.
Builder A	Builder A is an experienced site manager with over 10 years' experience within the industry. Builder A specializes in the inspection and handover stages of a construction project. He has inspected over 240,000m2 of office space to date and on this particular project leads the building team.
Builder B	Builder B holds a degree in architecture as well as a Masters in building and construction. Her role on this project is to solely work on defects inspecting the building, which involves record all the defects identified by the builders and architects then forward these lists onto the tradespeople for rectification.

3.2 Data collection

The study involved the investigators observing closely with a team of stakeholders, in particular, the architects and builders as they inspected a purposely-built academic building for defects. Over an intensive fourteen-week period the investigator was involved in iterative set of on-site observations, interviews, documentation analysis. At the conclusion of each observation session, investigators (one with construction domain knowledge) would compare notes to see if what had been observed concurred with one another. It also provided a useful check and balance through the data collection stages. Each re-iteration involved feedback, re-discussion of observations and re-questioning of the participants to validate observations and conclusions of the investigator throughout the process. The data collected was interpreted through a hermeneutic lens of feedback, interpretation, observation and interpretation. Nvivo was use to organize and analyses the data collected. The NVivo software used tagging with theoretical and empirical studies labels with interview notes and transcript texts and then categorizing text into defined themes. The power of NVivo as an analysis tool is in its bringing together strands of data, observations or comments enabling the analysis, the mapping out the concepts involved and establishing the relationships between them. It allowed the investigators to identify trends and cross-examine the data in through a series of queries, which in turn lead to series of conclusions.

4. Findings

This study highlighted a number of factors that have contributed to the knowledge surrounding information used, shared, stored and managed, within the defects inspection phase of the case study construction project. The findings identify the importance of issues relating to process, domain knowledge and issues that could obstruct the efficiency and effectiveness during this phase of the construction process.

4.1 Various information management methods

Even the role and responsibility of each stakeholder were different. However, they were working toward the same building completion deadline. Data collected from observations found that there were differences in the ways that information was recorded, codified and stored between architects and builders.

Architect A versus Architect B
During the defects inspection Architect A usually recorded all his notes either in a notepad or on printed versions of the drawings. He then headed back into the office and created his own sets of notes. Architect B used a similar method but he often used a camera to take photos on site as additional information for further analysis when he got back to the office. Both architects had different information codification methods. Architect A used a colour scheme when he recorded defect information. For instance, any issues that were urgent and required immediate attention would be record in red, any on-going issues that required further clarification would be written in black and finally any items that have been rectified would be written in green. As for the mark-up of the drawings Architect A made use a highlighter to highlight the area and then add his own comments beside it. Architect B recorded all note in black (no use of colour) and codified his notes in an ad-hoc manner; sometimes he would note the information in his notepad under the date of inspections whilst others would be organised under a description of the room. Once Architect A has arrived back into the office, he then scanned his notes and drawings and uploaded them into a company online repository system. Architect B would often head back to the office and type up meticulous notes and email them back through to the builders. Any photos that were taken would be printed out and attached to the notes as well as being uploaded to an online repository system.

Builder A versus Builder B
Most of the time during defect inspection both builders were on-site together. Most information was recorded by Builder B (who was a junior member of the team). Occasionally Builder A recorded his notes into his mobile phone and sometimes photos were taken. Most of the information both builders recorded were rectify instructions from both architects. From observations, the researchers found that Builder B was switching information-recording methods between a tablet device and traditional paper notepad. The tablet device contains “in house” software that was designed to record information during the construction process with a synchronised ability with the PC at the office. Both builders used the same method of information codification. They referred to all information noted by room number which was shown in the drawings. The builders emailed all information out of their mobile phones and managed those notes and photos with their PC at the site office. While Builder B had both codified (from the tablet device) and un-codified information (written note form her notepad), she often spent large amounts of time managing it at her computer at the office. The research indicates that there was various information management methods used during the defect inspection process. Although the stakeholders acknowledged the formal information management structure that was in place, they would often make use of and rely on their on the methods that they have been accustomed to. Information sharing resulted, often serendipitously, sometimes formally through email exchange and most often through instructions to those mandated to do the rectification work. The process appeared chaotic, but in the view of the stakeholders, ‘worked’.

Builders versus Architects
Occasionally, Architects A and B used defect notes as a cross checking references. As they inspected the same areas in the building most of the notes recorded were similar defect spots. However, the defect notes contexts were slightly different as Builders recorded the defects information from builder perspective which included how to rectify those defects. While Architects recorded information in an aesthetics contexts to compare with drawing and specification.

4.2 The role of knowledge and experience in different stakeholders

During the defect inspection process, information sharing occurred between architects and builders in various forms. The builders presented information in a form of constructed conditions, if it doesn't not match the information shown in the drawings or specification, the architects then had to share their information in a form of comments, rectification instructions or solutions to the problems. Data collected during the defect inspections showed that, senior architects (Architect A) relied more upon his tacit knowledge in his visual architectural domain rather than constantly referring back to explicit knowledge such as the drawings or any other specification documents. *"I think he has been doing it for a long time, he goes a lot more intuition, visual, you know, I don't have a plan, he'd be like it doesn't look right therefore it mustn't be right."* Builder B also demonstrates how Architect A used his tacit knowledge. "*He ultimately has been around a lot longer and knows … knows the process of defecting and what his role and the builder's role is"* **(**Builder B); while the less senior architect (Architect B) from the same company relied more on explicit knowledge through the use of documented drawings and schedules. He said: "*It's very important to always carry the drawings and schedules for specification with you and to be able to answer any questions otherwise you cannot answer any questions that come at you"* **(**Architect B). The different levels of tacit knowledge and experience in both architects had an effect on their subsequence decision-making during the inspection process. This is because Architect A (who has more experience) was often able to solve the problems on the spot, while on many occasions Architect B had to refer to drawings and documents when he got back to his office before the decisions were made. Again, effective information sharing happened, albeit within a context of different decision-making methods used.

4.3 The complexity of information and the dynamic nature of information sharing

There were a vast amount of defect lists created by both parties (architect and builders). In total, over fifteen thousand defects were identified and rectified through the use of this process. Like many others construction projects, the defects inspection process occurred in parallel with the fit-off (finalisation) of the building, which, in turn, made it difficult for the parties involved to work in a systematic manner and perform their primary duties of 'defecting' the building. It was observed that the stakeholders would often switch from one space to another without adhering to the originally agreed plans. This was mainly due to the constant distractions from construction workers who were working on other aspects of the building. The construction workers often required instant clarification from builders in order to continue on with their tasks. It was these small but constant distractions, which lead to additional inspection times being scheduled around the architects and builders already busy agendas. Being dynamic in nature allowed the information to be shared and managed amongst the stakeholders both informally and formally and for the intensity of this information to be varied according to the task that needed to be completed. However, the goal of completion deadlines agreed amongst the stakeholders' motivated information sharing to assure effective project completion.

5. Conclusion and Discussion

The finding revealed that although there was enterprise information management system (in house software) in place to deal with the complexity of information within the defects inspection stage, these practices often were supplemented by the different information management methods that each stakeholder was accustomed to. Even the in house software was useful however, in some construction site conditions stakeholders found it impractical. This impracticality made stakeholders develop methods to handling information management on construction sites differently. These different practices were ultimately influenced by their specific domain knowledge, experience and the amount of explicit and tacit knowledge they possess.

The study also revealed that the information management and information sharing on this particular construction project was dynamic in nature, with different stakeholders taking charge at key stages. Being dynamic in nature, facilitated the formal and informal exchanges with information as well as the ability to alter the intensity of information being disseminated by the key stakeholders.

From the perspective of information management practices within the construction industry, there needed to be a greater awareness of effective information management practices, in particular the defects inspection process. The study revealed that stakeholders perceived information management under the premise of construction management as this was their primary area of specific domain knowledge. The study demonstrated that it was a combination of personal experience and dynamic nature of the defect inspection process that allowed the stakeholders to successfully guide the construction project to finish on the agreed time frame. However, having a greater understanding of information management practice may facilitate a decrease in the number of defects and re-work that often occur in every construction project and ultimately reduce the construction timeframe. If the amount of re-work in construction projects can be reduced or eliminated, then the construction process effectiveness then can be improved.

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