Transition from Design to Construction:

Losses in Knowledge and Tools for their Minimisation

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Lost In Transition*

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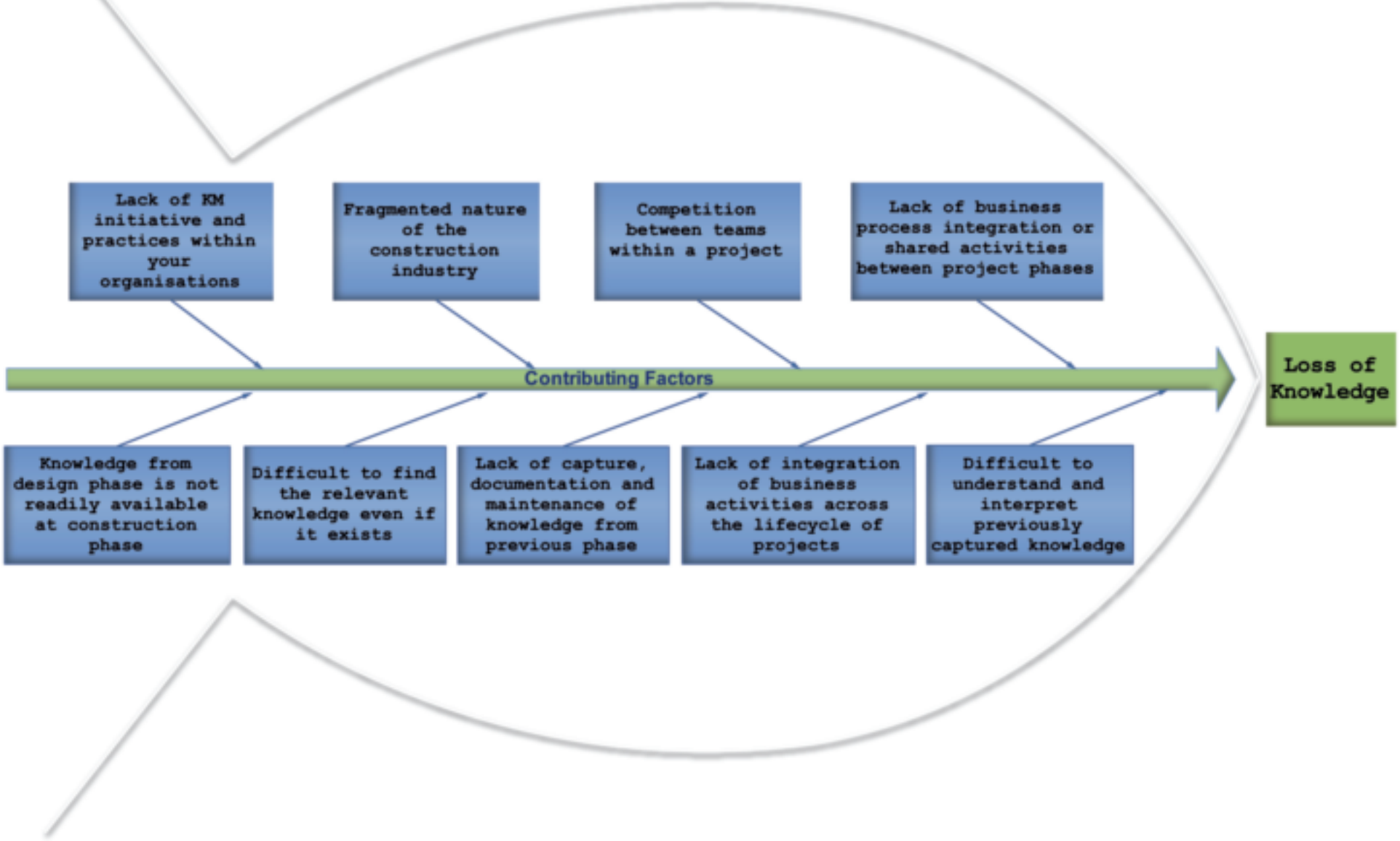

Executive Summary

This report presents the findings of a six-month research project – '*Lost in Transition'*. The research was carried out by a multidisciplinary team at Loughborough University and was aimed at identifying knowledge management issues that can lead to loss of knowledge. Construction projects go through series of phases during which several activities are performed by multiple stakeholders. This requires *information* and *knowledge* supplementary to the competences of project teams. This involves knowledge management (KM) processes to adequately capture, document, store, share, use, refine and reuse the knowledge from one phase to another and from project to project. However, due to certain KM issues, knowledge is lost as the project progresses from phase to phase. Several factors contribute to this phenomenon thus the investigation of this research.

In order to comprehend the underlying issues of the phenomenon and to propose suitable solutions, the research conducted a Delphi inquiry method to collect data. Interviews were conducted as the first round of the Delphi study followed by a focus group workshop which served as the second iteration. The research examined the different tools used for documenting, communicating and sharing knowledge. It also examined the different transitions between phases of a construction project that require the most focus of KM. The study examined the contributing factors of loss of knowledge in order to determine the major contributors. Data collected was analysed using both quantitative and qualitative analysis methodologies.

The study found and confirmed that multiple factors contribute to loss of knowledge and identified four major contributors: 1) *Lack of business process integration and shared activities between project phases; 2) Lack of capture, documentation and maintenance of knowledge from previous phase; 3) Fragmented nature of the construction industry; and 4) Difficulties to find the relevant knowledge even if it exists*. The study also identified '*email*' and '*meetings*' as the most preferred tools/techniques for knowledge sharing, with digital documents for their documentation.

Recommendations were made based on tangible proofs to remedy the loss of knowledge. The main focus for this is '*knowledge retention*' and includes: the development of a knowledge retention framework, *new* KM tools (*incorporating email*) for individual phases and the integration of construction business

processes to facilitate shared activities across the lifecycle.

1 Introduction

This report presents results from a six-month research project, '*Lost in Transition'*, conducted by a multidisciplinary group at Loughborough University aimed at identifying knowledge management (KM) needs during the processes of designing, constructing and managing buildings. The project followed the flow of "knowledge" through the various building life-cycle phases to determine how to reduce the losses of knowledge at the transitions between phases.

This research first reviews related work on knowledge management in construction projects with the view to understand current trends and to identify contributing factors to loss of knowledge in transition between project phases. Secondly, a description of the research methodology is made detailing how the research was conducted. Thirdly, findings are presented and analysed and finally, an explanation of the conclusions and recommendations is made.

1.1 Objectives

To meet the aim of the project, which is to identify KM needs during the processes of designing, constructing and managing buildings, the following objectives were established:

- To describe and investigate the flow of knowledge within a construction project;
- To identify the losses of knowledge that occur at the transition between various phases (with emphasis on the transition from '*design to construction*'); and
- To propose KM solutions to minimise those losses.

2 Knowledge Management

The construction industry is characteristically recognised and dominated by a project-based paradigm of delivery of unique products and services (such as buildings) by multiple organisations (Kazi, 2005). During the process of designing and constructing the building, a large amount of information is produced; valuable experiences and lessons are gained, which if not properly managed (i.e. documented and shared broadly) may be ***lost*** (Kazi, 2005). The importance of Knowledge management is gaining recognition by many organisations in their quest of creating value for their customers, gaining agility in responding swiftly to changing business environment (Carrillo et al., 2003a; Latham, 2005). This

is emphasised by Michael Latham in his foreword to *Knowledge Management in Construction* by recognising the essence of KM for improving construction project delivery processes and to sustain productivity (Anumba et al., 2005). KM is essential to prevent "wheels being reinvented" and mistakes repeated from project to project. For example, capturing design information permits knowledge to be shared and revisited by various stakeholders and can reduce the time it takes for new team members to get 'up to speed' (Fruchter and Demian, 2005).

During design and construction phases, different stakeholders and teams of various disciplines and organisational cultures using different information systems come together to design and build a building (Otter and Emmitt, 2007; Emmitt and Gorse, 2007; Anumba et al., 2002) which makes information sharing and knowledge communication a challenge. The heterogeneity of stakeholders and "knowledge" (documents and content) in construction projects means that KM is particularly challenging; arguably more so than in other industry sectors and contexts because of the fragmented nature of the supply chain and the 'one-off' nature of projects (Ruikar et al., 2009; Carrillo et al., 2003b), in which a project organisation comprised of members from diverse organisations effectively builds a 'prototype' before disbanding.

KM in construction begins with information about requirements. This comes primarily from user groups: occupants, maintainers, managers of buildings. Information about requirements can also come from designers and construction workers. Requirements information leads to engineering specifications. This comes primarily from the core design team led by an architect. Significant contributions to engineering specification information can also be made by specialist design consultants or contractors.

Engineering specifications lead to construction information and knowledge: the drawings and specifications used to construct a building as well as the workflow documents used to manage the construction process and the professional expertise driving this process. This information is generated collectively by the design team, the general contractors and the various specialist subcontractors involved across the lifecycle processes. Different working methods and procedures are used to create, store, distribute and apply knowledge according to particular business processes which have to be integrated into a KM approach that is

oriented towards business processes (Heisig, 2001). Therefore, to facilitate knowledge retention, KM must be woven within organisation's daily activities; particularly, to "anchor knowledge sharing activities in core business processes" (Liebowitz, 2009)

This indicates the need to derive mechanisms for documentation, storage and retrieval of construction information and knowledge across the whole lifecycle processes and in between the people and systems. The recent emergence of Building Information Modelling (Eastman et al., 2008) may provide a vehicle for enabling this approach of a holistic KM solution which encompasses all phases, stakeholders and types of content in construction.

Knowledge retention is an important part of KM whose goal is to identify critical skills, experiences and relationships possessed by employees (especially experts) and to ensure other staff (such as junior employees) acquire and reuse such know-how for continued success, improved innovation efficiency, organisational growth and competitive advantage (Liebowitz, 2009). This reuse could be both internal and external knowledge reuse (Demian and Fruchter, 2006).

Access to and sharing of project knowledge during the phases of a construction project is a relevant enabler to completing projects on time and to budget. This was emphasised by Lee and Egbu (2008) who identified that frequently available knowledge is only accessed when a process comes to a standstill as a result of a problem, and there is generally a lack of comprehension of the value of the integration of process and knowledge. Various types of communication channels and media (*such as email, meetings, project extranets, videoconferencing, telephone, individual dialogue*) are used in construction; for this to be effective, teams have to use a mix of the different communication channels and media (Otter and Emmitt, 2007). Several KM tools have been identified which are divided into KM techniques and KM technologies (Al-Ghassani et al., 2005). KM techniques are non-IT tools that do not require technology to support them and include Communities of Practice (CoP) and brainstorming whilst KM technologies are IT-based and require IT platforms for their implementation. These include knowledge based systems and case-based reasoning (Al-Ghassani et al., 2005).

According to Otter and Emmitt (2007) communications can occur *synchronously* (i.e., in real-time using

electronic means) or *asynchronously* (i.e., at different times using electronic means). Anumba et al. (2002) defined four models of collaboration which include Face-to-face Collaboration, Asynchronous Collaboration, Synchronous Distributed Collaboration and Asynchronous Distributed Collaboration, which depend on the nature of separation and pattern of communication. Knowledge can be embedded in many different media such as text documents, optical media (e.g. CDs), computers (databases, intranets, and extranets) and in people's heads. The capability to communicate and share the various forms of knowledge from multiple sources can be challenging especially in a dynamic environment executing different activities, but is crucial to the success of projects because it facilitates an integrated approach to access and utilisation of project knowledge (Tserng and Lin, 2004).

Managing knowledge at phase-level according to the various activities (i.e., activity-based knowledge management) has been suggested to provide a better approach to knowledge management and to develop knowledge management systems (Tserng and Lin, 2004; Hasan and Gould, 2003). According to Tserng and Lin (2004), an activity-based approach is better than the 'whole project' knowledge management approach as the information and knowledge about the same or similar activities across the lifecycle can be identified, referred to and reused in other phases or other projects, and can facilitate classification and searching of knowledge according to activity-based units.

KM technologies such as *institutional repositories* (Liebowitz, 2009) and *corporate memory* (Fruchter and Demian, 2002) can provide effective force towards improved collaboration, capture, and sharing of knowledge when properly integrated with effective processes and procedures (Liebowitz, 2009). Several factors have to be considered when creating knowledge retention strategies and four key pillars were identified by Liebowitz (2009) to enable knowledge retention. These are:

- Recognition and reward structure: promote and establish a recognition and reward structure for knowledge sharing within organisations in order to encourage knowledge sharing and retention;
- Bidirectional knowledge flows: where knowledge flows from *bottom up* and *top down* (i.e. learning from each other between senior and junior employees);
- Personalisation and codification: Personalisation approach emphasises the *connection* part of KM such as mentoring, job shadowing, CoP

amongst others; whilst codification approach focuses on the *collection* or systems component such as the use of lessons learnt, after-action reviews, knowledge repositories on the intranet or other systems-oriented approaches;

- The Golden Gem: bring back or hire the talented retirees as contractors or consultants.

However, there are potential barriers to knowledge retention, including: misalignment between knowledge retention strategy and the strategic mission of the organisation (i.e., with the functions of the organisation), knowledge hoarders rather than knowledge sharers because of the believe that knowledge is power which gives value and competitive edge (Liebowitz, 2009; Leistner, 2010) and lack of specialist KM technologies due to high costs (Ruikar et al., 2007). Another important barrier is the lack of appreciation of the importance of knowledge capture by designers and as a result, knowledge is not captured (Fruchter and Demian, 2005).

3 Methodology

The aim of the project was to identify the KM needs during the processes of designing, constructing and managing buildings in order to minimise the loss of knowledge that occurs at the transitions between project phases. With this aim in mind, it was decided to solicit construction professionals for their subjective perceptions of knowledge flows and knowledge losses during a project. Interviews and workshop were conducted. The population identified for this research was construction project practitioners and stakeholders from which a sample was generated. A combination of snowball (Robson 2002, Gray 2009, Fellows and Liu 2008) and convenience (Fellows and Liu, 2008; Bryman, 2008) sampling methods were used to generate the samples for both the interviews and the workshop.

The interviews and workshop were conducted to help identify KM problems that could potentially cause loss of 'knowledge' by drawing upon participants' expert knowledge. The objectives were to collect data iteratively with participants of both the interviews and workshop; and to reach consensus on factors contributing to loss of knowledge. As a result, data was collected iteratively using the *Delphi technique*. The first iteration of data collection entailed semi-structured interviews and the second was through a workshop as illustrated in Figure 1. Both the interviews and workshop were conducted using a questionnaire as a guide.

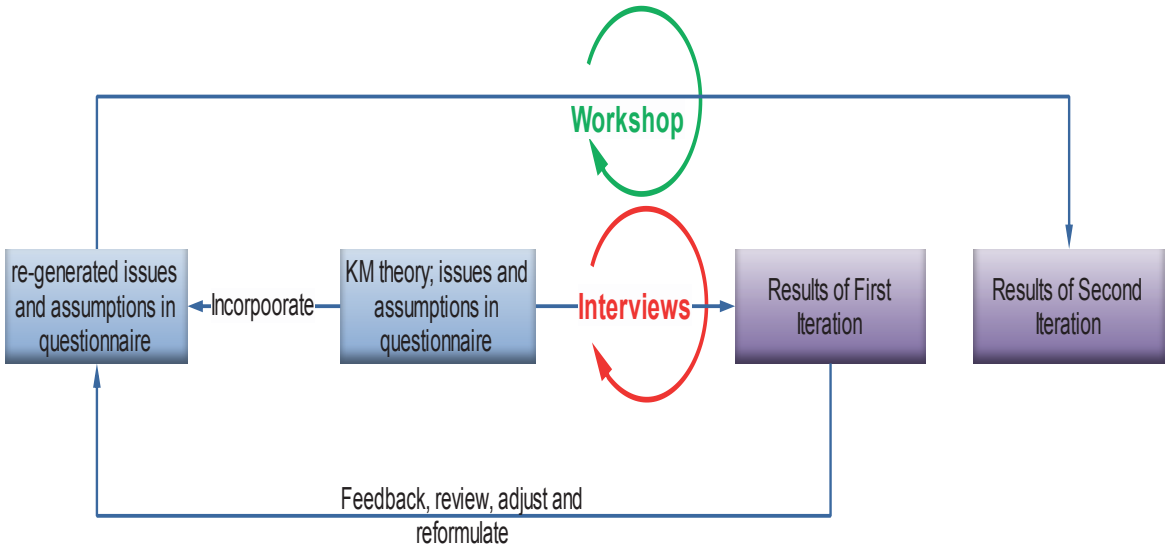

Figure 1: The Data Collection Process

The key focus of the questionnaire was to collect data on different aspects of KM in construction projects to facilitate identification of problems and factors that contribute to knowledge loss. The questions on the questionnaire were developed on particular key areas and theories covering the entire KM lifecycle, issues and assumptions. These include the *status of KM within their organisations, the tools/techniques they used the most when sharing knowledge, the transition phases they regard as requiring most focus on KM, their preferred medium for knowledge documentation and their perception of the contributing factors to loss of knowledge*. These questions were relevant in determining issues and factors contributing to knowledge especially the types of tools used for sharing knowledge. Another important area was the question about the transition between phases that requires most focus on KM. This will help identify the project phases on which professionals must mostly focus their KM efforts thus revealing other phases that would require attention in order to avoid or minimise knowledge loss. Initially, eleven contributing factors were identified through the literature and used in the interview questionnaire. However, following initial analysis of the interview results, these were refined and reduced to nine as shown in Table 1. The reason for this was that two items were regarded as repetitive and were incorporated into other factors in the list.

Table 1: Factors Contributing to Loss of Knowledge

No	Factors Contributing to Loss of Knowledge
1	Lack of KM initiative and practices within your organisations
2	Fragmented nature of the construction industry
3	Competition between teams within a project
4	Lack of business process integration or shared activities between project phases
5	Knowledge from design phase is not readily available at construction phase
6	Lack of capture, documentation and maintenance of knowledge from previous phase
7	Difficulty to find the relevant knowledge even if it exists
8	Lack of integration of activities across the lifecycle of projects
9	Difficulty to understand and interpret previously captured knowledge

Following the development of the sampling frame, it was then necessary to send invitations for participants to take part in the interviews and the workshop. Twenty-five invitations were sent to industry professionals to participate in the interviews. Interviewees were selected based on the individual's expertise and role within their projects through a snowball sampling method. All invitations were sent to professionals who were either involved in an on-going project or a completed project of the same client. Out of those invitations, 4 interviews were conducted which included a centre manager, QS, M&E Consultant, and a project manager as shown in Table 2 representing 16% response rate. Probably the most widely used method in qualitative research (Bryman, 2008), interviews are an effective technique of collecting data and when conducted properly, a vast amount of data can be collected within a short period of time. Each of the interviews lasted about an hour and was audio recorded and transcribed.

The interviews were semi-structured and guided by a predetermined interview plan or questionnaire (Appendix A) (*which had a mixture of open, closed and Likert-scale questions*). Interviews were partly structured to ensure all the participants were asked similar questions in order to conform to the Delphi

technique. Semi-structured interviews can be used to develop conversation on a topic but not necessarily in any strict order (Gibson and Brown, 2009). However, interviewees were given space to deliberate on their answers, which facilitated their comprehensive participation (Fellows and Liu, 2008).

Table 2: Interviewees Roles/Disciplines and Project Types

Role/Discipline	Type of Company	Number of Interviews
Centre Manager	Client organisation	1
Quantity Surveyor	General contractor	1
Mechanical Engineer	Consultancy firm	1
Project Manager	Consultancy firm	1

Following the initial iteration of data collection through the interviews, a second iteration was required as stipulated by the Delphi technique to reach consensus (Fellows and Liu, 2008). Consensus was important for this project because of the involvement of different disciplines in a construction project, each having different perceptions regarding knowledge losses in construction projects. Rather than conducting a second round of interviews, the second iteration was a workshop comprising 11 construction practitioners as shown in Table 3 from a construction project. The sample of the workshop was selected through snowball and convenience sampling methods. This was done with the assistance of the consultant project manager of the project who facilitated the involvement of the participants through one of their project monthly meetings. The participants were also recommended based on their expertise and experience in construction projects.

The workshop was important to help the research explore KM problems and identify contributing factors to loss of knowledge. It was held on the construction site of the project which was a conducive environment for the participants as they did not have to travel away from work. It was also a familiar location which contributed to their effectiveness during the workshop. In attendance were three academics; although present, they were there only as coordinators and their

presence did not interfere or invalidate the workshop.

The Lead Author served as workshop facilitator. At the start, the facilitator thanked the participants for attending and introduced the purpose and rationale of the workshop. The participants also introduced themselves, describing their expertise, experiences and roles within the project. Workshop participants completed a questionnaire (*which had closed and Likert-scale questions*) using 'PowerPoint' and an 'Electronic Voting System' to give immediate feedback, facilitate iterative questioning and capture data from respondents. Each participant was given a handheld electronic voting device which they used to complete the questionnaire. This facilitated the immediate and 'real time' capture and storage of responses from participants. In line with Delphi technique, participants' responses were anonymous during the workshop which was also audio-recorded. The questionnaire (Appendix B) was designed reflecting the initial responses from the interviews. For some parts of the questionnaire, questions had to be answered twice. This was done to find out if respondents would change their answers the second time after discussions are held on the results of their first set of choices. Some of the questions requested participants to respond by selecting multiple answers (*in order of preference with the favourite first*) from the multiple choices of each question.

Table 3: Workshop Participants

Role/Discipline	Number of Participants
Client	1
Architect	1
Mechanical Engineer	2
Contractor	4
Project Manager	1
Others	2

Several issues had been reported as contributing factors to the loss of knowledge in construction projects both from literature and the interviews. The research identified nine main factors (Table 1) categorised according to the knowledge management lifecycle and each factor was developed into a question

within the questionnaire (Appendix B). The questions (7-15) asked participants to indicate to what extent they agree that each factor contributes to the loss of knowledge by selecting one from a possible five answers including: *'Agree Strongly', 'Agree', 'Don't Know', 'Disagree', or Disagree strongly' (using a Likert scale of 1 – 5)*. Each of these questions had two rounds of voting sequentially where participants had the opportunity to either change their mind from the first round votes or maintain their initial choice. An example of such a question was: *To what extent do you agree that 'Fragmented nature of the construction industry' contributes to loss of knowledge?*

(I) Agree Strongly (II) Agree (III) Don't know (IV) Disagree (V) Disagree Strongly

The 'Electronic Voting System' was a perfect tool for immediate collection of the data (through the hand held devices) and analysis presenting the results in graphical form instantaneously. Before conducting the second round of voting, results from the first round were presented for discussion during which participants deliberated freely on the results. Some participants, depending on the discussions, changed their mind and voted differently in the second round of voting. This was helpful in generating a consensus on the factors thus conforming to the Delphi technique. In the last question, all the nine factors were put together as 'multiple choices' into a single question and participants were asked to select their top three contributors to loss of knowledge, ranking them in order of their preference with strongest first.

The workshop lasted for an hour. At the end, the facilitator summarised the topics discussed and the major points that were contributed by the participants. At this stage, participants were allowed to react to some of the points by further clarifications and comments. This method of conducting a workshop as the second iteration of the Delphi technique was advantages in two ways: (i) logistically, it enabled rapid iteration of the questionnaire by all participants, (ii) the use of the Electronic Voting System provided anonymous response from the participants which conforms to Delphi technique, and (iii) it facilitated open discussion on the results which provided comprehension and contributed to consensus.

Thematic analysis was used for the analysis of the data collected (Swenden, 2006; Boyatzis, 1998). The data collected in both the interviews and workshop was thoroughly examined and categories established. Similarities in the data were identified which resulted in the grouping

of similar data under different categories. These categories were further classified, coded and sub-divided into different key themes relevant to providing answers to the investigation. The themes were used to present the results and formed the basis for the analysis of the findings in Section 4.

4 Findings, Analysis and Discussions

Two sets of data were analysed: first, the interviews and second, the workshop. The analysis also took the form of triangulation were both quantitative and qualitative (statistical and thematic respectively) analysis were applied. This was necessary to suit the different data sets generated from the responses. Interesting themes emerged including knowledge as a critical resource; acquisition and documentation of knowledge; access, sharing and communication of knowledge; interpretation and use of knowledge; and stimulating factors and contributors to loss of knowledge. The themes were used in the study as focal points for the analysis and discussion of the collected data, to determine their effect on loss of knowledge.

4.1 Interviews

4.1.1 Information as a critical resource and KM focus on transition phases

In order to ascertain interviewees' perception of the value of information and knowledge, they were asked about their view of design information as a critical resource in the transition from design to construction. It was fitting to understand their perception of this as it could reveal their behaviours and attitude towards KM activities in their organisations. All four interviewees regarded design information as a critical resource.

Is Information a Critical Resource?
"Yes, it is critical. If lost, it will have detrimental impact and can take up to about three weeks to get the information." (Quantity Surveyor)
"Yes, because things can change remarkably. You should know why things change." (Centre Manager)

They recognised that vast amounts of information come from different sources and it becomes difficult to realise what is essential to the end-user of information. According to them, loss of design information can have a detrimental impact,

causing enormous difficulties to the project as its regeneration could take a considerable period, thus delaying progress. For example, referring to the question if they regard design information as a critical resource in the transition between design and construction, the QS indicated that "*Yes, it is critical. If lost, it will have detrimental impact and can take up to about three weeks to get the information.*"

Reference was also made to drawings and specifications as very important assets as well as other types of information such as design briefs, minutes of design meetings and requests for information (RFI). Participants also highlighted the fact that projects are dynamic resulting in rapid changes. As a result, records (information) of such changes should be kept so that the reasons for the changes are known. For example, responding to the same question, the Centre Manager replied by saying "*Yes, because things can change remarkably. You should know why things change.*"

When asked about the type of information required from participants of other phases (*e.g., construction phase*) during the *design phase*, interviewees indicated that a *good design is iterative* which requires a series of information such as: use of building, users and occupants, available budget, land/site information, town plan, energy requirements, structural information. Other types of information that are required include: the construction process, end users' requirement for operation and maintenance to determine if the client will be capable of maintaining the completed building. However, the quantity surveyor from a general contractor of a *design-bid-build* project indicated that *design is a client-led activity and they as contractors do not get involved*. Nonetheless, at the construction phase, the general contractor would require design information including specifications but sometimes this information is incomplete and the design will be '*tweaked*' (adjusted or fine-tuned) by the contractor to make the design more constructible, according to the QS.

4.1.2 Knowledge documentation

Almost all the interviewees indicated that knowledge is first captured at the briefing stage when the client specifies their needs in a building. They highlighted that knowledge capture is made possible by documenting everything during a project. One interviewee responded by stating that "*We get things documented and keep things in files.*" Communication is essential in the process of knowledge capture and needs to be documented in order to acquire knowledge. It was also

pointed out that several mechanisms and processes for documenting communication and acquiring knowledge exist and are used in various projects. These included using project extranets, paper-files (such as drawings and specifications), emails, meeting minutes, technical reports amongst others. Interviewees described how they access and utilise the captured knowledge which is done by requesting and passing information in files either through project extranets, email or physical transfer of hard copies. Meeting minutes are also often recorded and distributed, but not to the whole project and are limited to those who attend the meetings. Drawings and specifications are also used as sources of knowledge and are carried forward from one phase to the next. Another source of knowledge is that held by experienced and expert construction practitioners. Such knowledge (tacit knowledge) is acquired through interactions between those who require the knowledge and the experts (Nonaka and Takeuchi, 1995). This according to them would include dialogues, observations and apprenticeship. According to the M&E consultant, another dimension of acquiring the knowledge includes *documenting lessons learnt (including challenges) from one stage to another and from project to project;* this knowledge is often embedded in informal conversations and email exchanges.

Therefore, communications must be recognised for knowledge acquisition. An observation made by the quantity surveyor was *the difficulty of using captured knowledge*. This observation, based on a general trend, was that in a design-bid-build project, designers manage their own system containing the documented information and this system is inaccessible to them as general contractor.

4.1.3 Tools/techniques for communicating and sharing knowledge

Results from the interviews indicated divergence of tools and techniques used for sharing knowledge.

Tool/Technique Used Most
'Email' emerged as the most commonly used tool followed by 'intranet' when sharing knowledge.

Different interviewees indicated tools and techniques they used when sharing knowledge within their projects. These were compiled and included: online chat, email, intranet, technical group, central archive, minutes, and document management systems as shown in Figure 2.

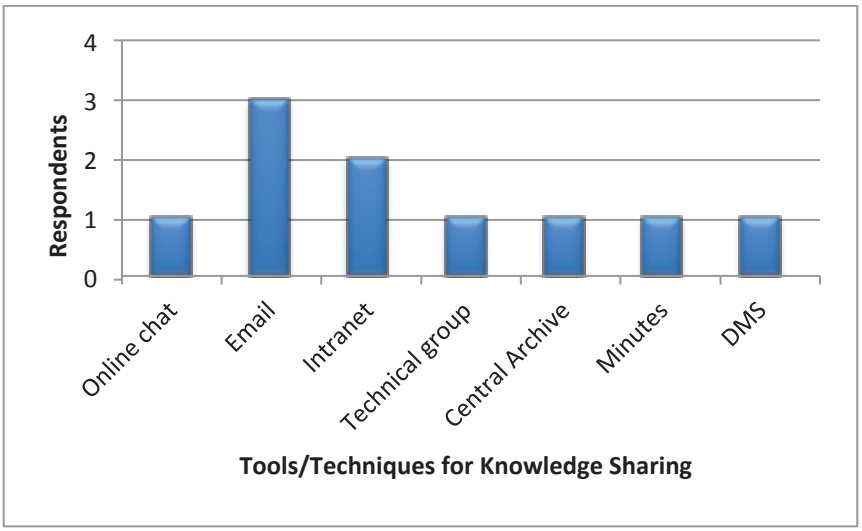

Figure 2: Tools/Techniques Used for Knowledge Sharing

These tools/techniques generated from the responses were all familiar tools/techniques used within the construction industry for sharing knowledge except *central archive* and *technical group*. According to the interviewees, central archive is a term used to mean a central computer storage space that provides an organisation the facility to archive electronic files which can then be accessed and retrieved by its members at different times. Technical group means a group of individuals mostly engineers, put together to discuss and report on issues of relevance to their work. Such a group is expected to write technical reports on problems encountered and their solutions; or the best approach to solve such problems.

This divergence of tools/techniques for knowledge sharing according to interviewees is as a result of the different nature of projects and sometimes client preferences for the type of tool to be used in a project. Despite the various tools/techniques listed being used in construction projects, '*email*' emerged as the most commonly used tool with a usage rate of 100% followed by '*intranet*' with 75% (3 out of the 4 interviewees) when sharing knowledge. The others (*online chat, technical group, central archive, minutes and document management systems)* each received 50% (2 out of the 4 interviewees) specifying their usage.

4.1.4 Knowledge retention and stimulus for loss of knowledge

Interviewees were asked to suggest ways to improve the retention of knowledge in order to minimise or avoid knowledge loss. All interviewees acknowledged the significance of retaining knowledge which can be beneficial from phase to phase and from project to project. Several

suggestions were made according to the different disciplines interviewed. The client indicated the value of recording/documenting the history of the project which includes: requirements, changes, minutes, etc. These were believed to carry vast amounts of knowledge in them thus requiring adequate documentation to prevent the knowledge they carry from being lost. A mechanical engineer suggested writing technical papers on project issues and where a difficult problem was encountered, engineers may be asked to document their experiences describing what the problem was and how it was remedied. The project manager and quantity surveyor highlighted the one-off nature of constructions projects and the associated difficulty of keeping the same staff from project to project. Consequently, they suggested that mechanisms should be put in place to enable staff retention; maintaining the right people from project-to-project.

Interviewees were asked to indicate how much they agreed with the statements given as factors contributing to loss of knowledge and to specify the top three. Following the tabulation of the results cumulatively, the following emerged as the top three as shown in Figure 3.

Top Three Contributing Factors
1. *Lack of capture, documentation and maintenance of knowledge from previous phase.*
2. *Lack of shared activities between project phases.*
3. *Lack of integration of business activities across the lifecycle of projects.*

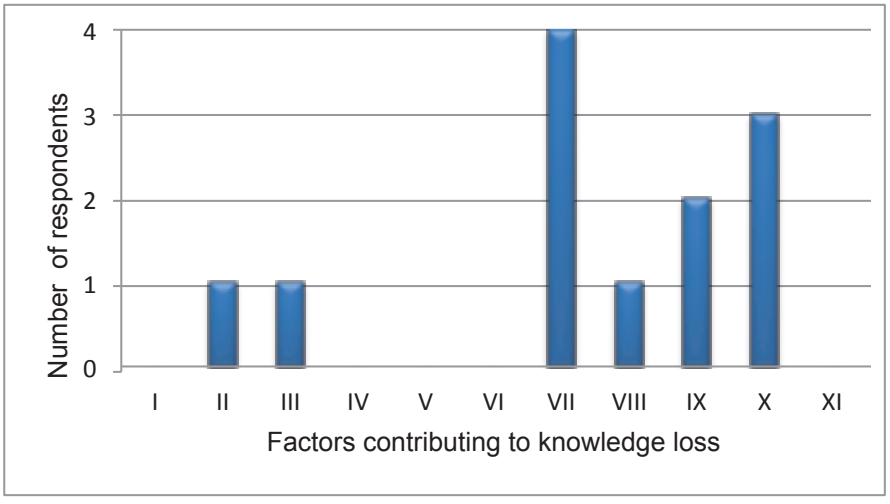

Figure 3: Top Three Contributing Factors to Loss of Knowledge

Key	Contributing Factors
I	Lack of KM initiatives and practices within your organisations
II	Fragmented nature of the construction industry
III	Competition between project teams
IV	Lack of business process integration between project phases
V	Knowledge from design phase is not readily available in construction phase
VI	Difficult to find the relevant knowledge even if it exists
VII	Lack of capture, documentation and maintenance of knowledge from previous phase
VIII	Lack of collaboration between teams operating at different phases
IX	Lack of shared activities between project phases
X	Lack of integration of business activities across the lifecycle of projects
XI	Difficult to understand and interpret previously captured knowledge

It is important to note that factors such as *I, IV, V, VI* and *XI* were not considered as factors contributing to knowledge loss. The reason for this was however not discussed during the interviews. This could be regarded as a limitation of the research.

4.2 Workshop

As discussed in the Methodology Section, the next stage of data collection was to explore, iteratively, further KM problems and to reach consensus on the factors contributing to knowledge loss. As a result, a workshop was conducted for this purpose. There were 11 attendees in total each representing a stakeholder group in the project. Participants' responses were captured through the handheld voting devices during the workshop. The outcome of the analysis was supplemented with observations and audio-recordings of the workshop proceedings.

4.2.1 Information as a critical resource and KM focus on project transition phases

This research investigated the loss of knowledge in transition between project phases with emphasis on the transition from design to construction. Therefore, it was ideal to understand from the participants the transitions between phases thought to require the most focus of KM.

Phases That Require Most Focus on KM
'Design to construction' transition phase appeared as the phase that requires the most focus on KM; as observed by the workshop, is much more technically challenging, complex, and requires the resolution of more issues.

The questionnaire asked the following question: "Which two project transition

phases require the most focus on knowledge management? (*Rank in order of preference with favourite first*)". This question was iterated as participants responded to it twice; the second followed discussion of the results of the first round. The results were aggregated and calculated such that for each participant, '*first favourite*' scored 2 points and '*second favourite*' scored 1 point. These were then added together to give a final score for each transition. Consequently, the '*design to construction*' transition phase appeared as the transition phase that requires the most focus on KM as shown on Figure 4.

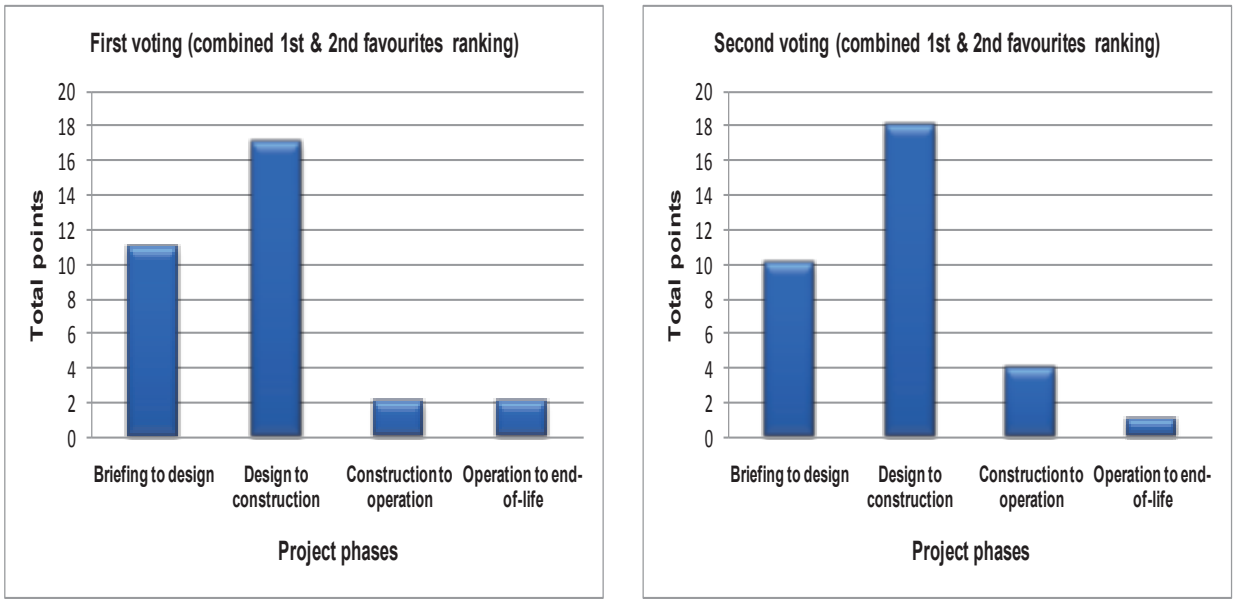

Figure 4: Project Transition Phases Requiring Focus on KM (1st and 2nd round votes)

The second round results indicated a small increase in points for *design to construction phase* (*first round = 17 points and second round = 18 points*) as a result of the discussions.

However, it was observed that the participants of the workshop were at that time involved in a project that was at the later phase of design (i.e., transition from design to construction) which might have influenced their response. It was also observed that the imbalanced representation (i.e., the different expertise and stakeholders) might have contributed to this as the majority of the participants were contractors, with one designer. Similar observations were made from the audio recording when participants discussed and confirmed this viewpoint by stating that most of the participants deal with design and if facilities management representatives were asked the same

question, *operations and end-of-life* could emerge as an important phase/transition. Similarly, if more clients were present, then the transition from *briefing-to-design* could have scored the highest. Some participants also observed that the transition from *design to construction* is much more technically challenging and complex, and requires the resolution of more issues.

4.2.2 Knowledge documentation

In establishing their preferred medium for construction information and knowledge documentation, participants highlighted that this can take different forms according to what information is being documented. If it is an architectural drawing, the preferred medium would be paper-form or hardcopy documentation. This is because quite often drawings are large-scaled which makes them difficult to view adequately on a computer display. Where swift information and/or decision are needed, then *email* with documents attached would be preferred. It was also indicated that Word documents in most cases are converted into Portable Document Format (PDF) for storage and distribution in order to protect from changes. As a result, *email* (the highest) and *digital document* formats emerged as the most preferred. Email also later came to light as an important tool for communication and knowledge sharing as described below.

4.2.3 Tools/techniques used for communicating and sharing knowledge

In order to determine the tools/techniques mostly used when sharing knowledge, workshop participants were asked to select which *two tools/techniques* they use the most when sharing knowledge, ranking their selection in order of preference with favourite first. The results indicate that '*email*' was most preferred followed by 'meetings' as shown in Figure 5. Participants deliberated that meetings are mostly used because of the value of bringing people around the table to share information and knowledge. Emails were regarded as too easy to write and copy people in resulting in information overload with important email messages buried amongst thousands of trivial communications. Responding to lack of traceability and miscommunications with emails, participants recognised that in every given project, there will be tens of thousands of emails from the beginning to the end and ultimately the percentage of missing or miscommunications that arise from them is really very small by proportion. Email was regarded as a tool that is quick to distribute information to different people and very easy to use. It

was recognised that when effectively managed (i.e., taking control and ownership, ensuring who needs to be copied and people taking responsibility for sending emails), then the negative aspects of emails (such as lack of traceability and auditability) may be minimised.

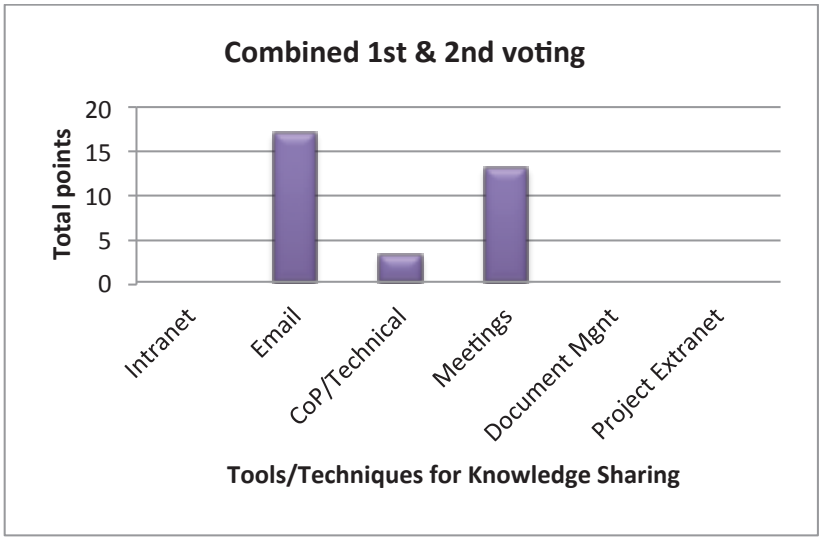

Figure 5: Tools/Techniques for Sharing Knowledge

Workshop participants observed that intranets and project extranets are used mostly in/for large projects when all drawings and files are required in one system and that probably is why they had not been used in the project in which they were involved at the time; because of its small size; it did not warrant the use of either. Responding to what is regarded as a large project or small project in terms of value, a £50-£60 million project would be regarded as large. It was recognised that a geographically dispersed project would require a project extranet as opposed to the one in which they were involved.

Consequently, the results indicated that different tools have used in terms of when and where the communication and sharing takes place (either *synchronously or asynchronously*) and whether co-located or distributed. In Table 4 the tools indentified and discussed during the Workshop are positioned in the two-by-two grid which categorises communication tools by whether the people communicating are co-located or distributed and whether the communication is synchronous or asynchronous (Anumba et al., 2002).

Table 4: Grid Showing Communication Tools and Their Application
Adapted From: (Anumba et al., 2002)

Synchronous	• Meetings • Face-to-face-dialogues • CoP/Technical groups	• No evidence of use
Asynchronous	• Project Extranets • Document Management Systems • Intranet	• Project Extranets • Document Management Systems • Emails
	Co-located	*Distributed*

From an individual discipline point of view (as shown on Figure 6), almost all the represented disciplines had selected '*email*' and '*meeting*' as their referenced tool/technique when sharing knowledge with the former (*email*) emerging as the most preferred.

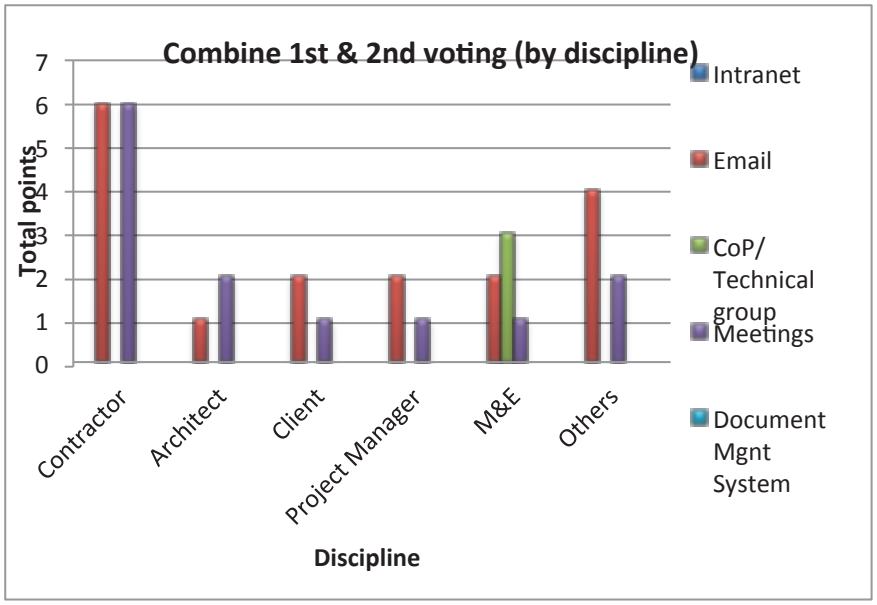

Figure 6: Tools/Techniques for Knowledge Sharing by Discipline

In order to provide a proportional analysis on the disciplines and their preferred tools/techniques for knowledge sharing, the results shown in Figure 6 were normalised by the number of respondents from each of the disciplines. This allows a fairer comparison between the different tools as shown in Figure 7.

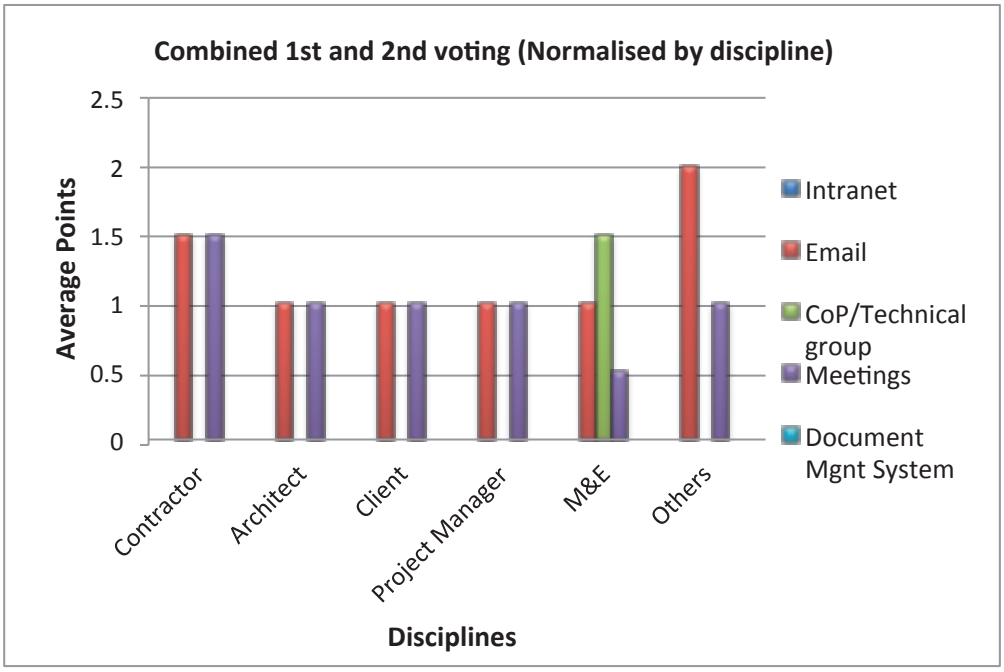

Figure 7: Tools/Techniques for Knowledge Sharing Normalised by Number of Respondents From Each Discipline

As indicated by the results shown on Figure 6 and Figure 7, both email and meetings are tools/techniques preferred by all disciplines. However, CoP/technical group was a tool/technique preferred only by the two M&E consultants and might seem insignificant in Figure 6 compared to email because of the low number of M&E consultants present during the workshop. However, in Figure 7, it emerges that this tool may be comparable in preference to email and meetings.

4.2.4 Stimulus for loss of knowledge

Out of the nine main contributing factors to loss of knowledge, participants responded by selecting their top three contributing factors with favourite first.

Top Four Factors Contributing to Knowledge Loss
1. *Lack of business process integration and shared activities between project phases.*
2. *Lack of adequate capture, documentation and maintenance of knowledge from previous phase.*
3. *The fragmented nature of the construction industry.*
4. *Difficulties to find the relevant knowledge even if it exists.*

Their selections were calculated such that for each participant, *'first favourite' scored 3 points, 'second favourite' scored 2 points and third favourite scored 1 point*. The results were aggregated and statistically analysed; and the findings indicated four main factors (shown in

Figure 8) that emerged as the most important. These were:

Lack of business process integration and shared activities between project phases

The majority of the participants agreed with a combined total of 14 points that lack of integration between the business processes of the different phases across the lifecycle contributes to loss of knowledge.

Lack of adequate capture, documentation and maintenance of knowledge from previous phase

With total combined points of 13, participants believed that without capture and documenting the knowledge in the first place, there will be nothing to retain. In the same vein, it was agreed that maintaining (as well as refining and updating) of existing knowledge is crucial in preventing loss of knowledge.

The fragmented nature of the construction industry

The industry is renowned for its fragmentation in nature and this was echoed by the participants. With a total of 8 points, participants regarded this as a major cause to loss of knowledge because the different teams and organisations which come together during a project each run and maintain their own KM systems and processes; and they disperse after a project taking with them the knowledge they held. Other parties are unable to access this knowledge when needed in other projects or at other phases.

Difficulties to find the relevant knowledge even if it exists

Participants highlighted the fact that often vast amount of knowledge resides in different sources and in different formats in project environments. However, with a combined 8 points, it was emphasised that it is difficult to locate or trace the knowledge required despite its existence.

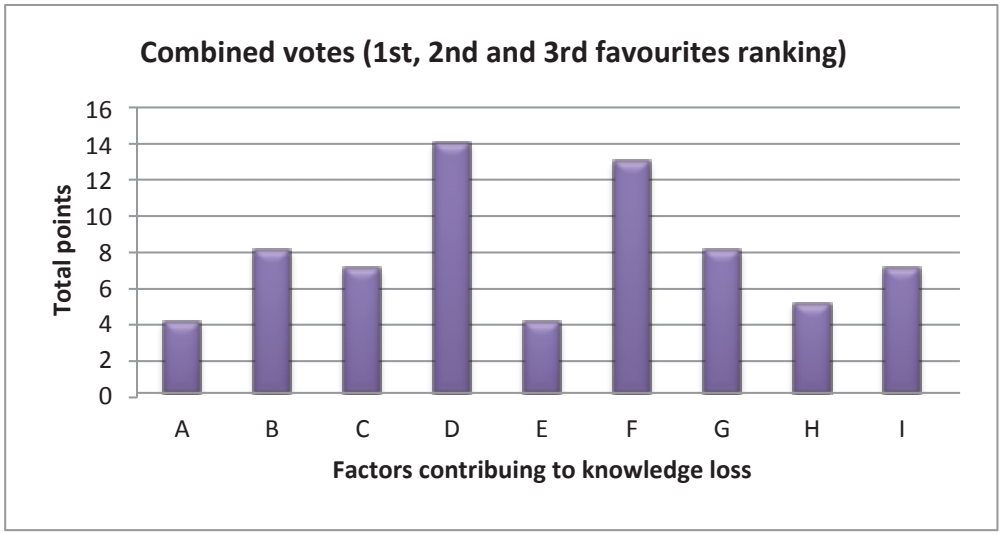

Figure 8: Contributing Factors to Loss of Knowledge

Key	Contributing Factors
A	Lack of KM initiative and practices within your organisations
B	Fragmented nature of the construction industry
C	Competition between teams within a project
D	Lack of business process integration or shared activities between project phases
E	Knowledge from design phase is not readily available at construction phase
F	Lack of capture, documentation and maintenance of knowledge from previous phase
G	Difficult to find the relevant knowledge even if it exists
H	Lack of integration of activities across the lifecycle of projects
I	Difficult to understand and interpret previously captured knowledge

4.3 General Discussion

Factors Contributing to Loss of Knowledge

Coupled with the fragmented nature of the industry, lack of business process integration or shared activities between project phases is a major factor to loss of knowledge.

It is evident from the findings that several factors pose major challenges to knowledge retention and cause loss of knowledge in construction projects. In order to avoid or mitigate the loss of knowledge, a structured and effective communication mechanism needs to be established to facilitate the flow of knowledge across all project phases. This would include identifying the sources of knowledge at each phase and determining a standard format and language to enable its access, interpretation and consumption. Because the various project phases are related, being able to understand the linkages between the various activities of project phases and being able to determine

what to share, with whom, when and from where, is paramount. These linkages are important to understand if effective sharing is to take place thus requiring a paradigm shift to an 'activity-based knowledge management' approach to facilitate affective sharing and retention of knowledge. Tserng and Lin (2004) have suggested activity-based knowledge management for the construction phase but this research argues that this approach should take a lifecycle approach (i.e., spanning across all phases and not limited to only one). In this way, knowledge will be managed at phase-level according to activities. These activities will then be linked together where there are relationships across the whole project lifecycle thus providing an integrated solution. This approach will clearly help to identify the knowledge and the resources required to execute each activity. It will also help in understanding the workflow of the activities of each phase and their inter-connection with other activities across the lifecycle. This type of interdependence between activities has been studied and modelled for design activities (Austin et al., 2000) but there is scope for similar work across the lifecycle of buildings.

The workshop results also highlighted that different disciplines may have different approaches to KM and perceptions of what contributes a loss of knowledge. As shown in Figure 9, almost all the disciplines involved in the workshop identified *Lack of business process integration or shared activities between project phases* is a major factor to loss of knowledge. The *fragmented nature of the industry* was also believed to be a major contributing factor by most of the participants. Participants recognised that if there was a single entity that manages the whole construction process (just as in the case of Manufacturing); ultimately processes like knowledge capture, data management and control, etc probably would be more efficient and streamlined. Participants made reference to their representative companies having their own procedures and systems of retaining information which could cause inherent inefficiency.

Competition between teams within a project was another factor thought to contribute to los of knowledge because of unwillingness to share certain information. Commercial sensitivity was regarded to be the cause of this. This was further clarified that teams come together to build a project but at the same time protect their company's interest. Emphasis was placed on sharing but not to publish sensitive information that may be of commercial advantage to ones company because of the

nature of the commercial world. As a result, 64% 'agreed' with the statement in the second iteration as opposed to the initial 45% who agreed in the first round of voting. Nonetheless, the word 'competition' was regarded not suitable for this context because it was not believed that any direct competition could exist between the different teams within a single project (e.g., competition would not exist between a contractor and the consulting firm).

Another factor that generated an interesting outcome was '*difficulty to understand and interpret previously captured knowledge*' which each of the disciplines agreed contributes to loss of knowledge. The use of different terminologies, language of the teams coming together in a project may be a cause.

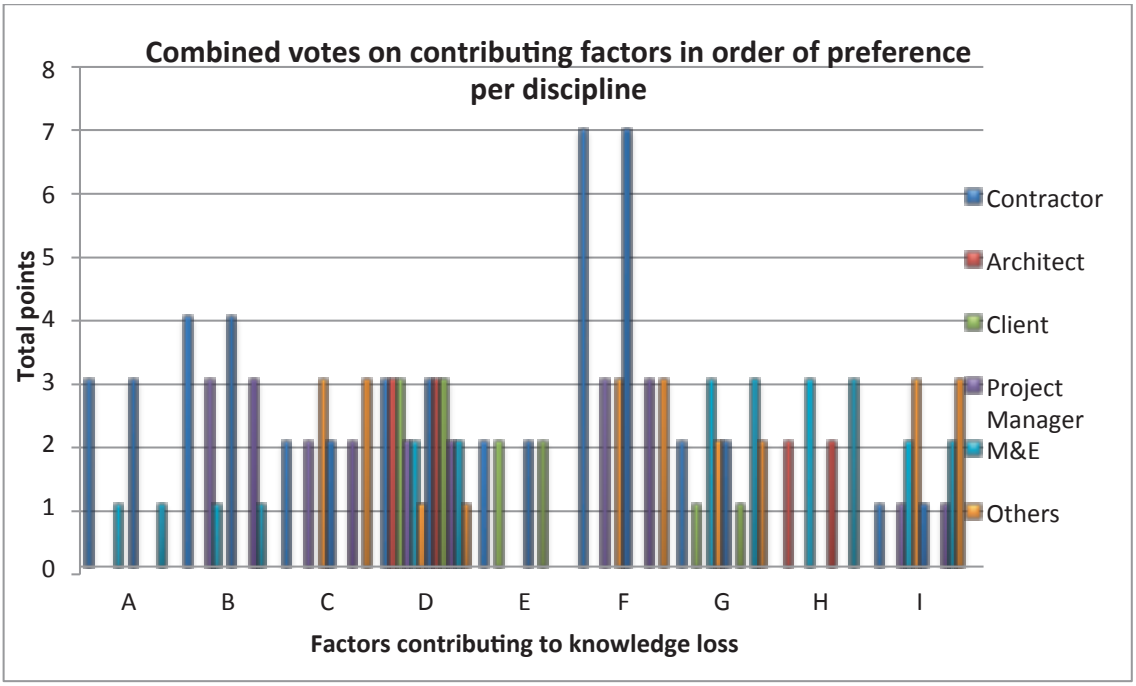

Figure 9: Results of Contributing Factors as Per Discipline

Key	Contributing Factors
A	Lack of KM initiative and practices within your organisations
B	Fragmented nature of the construction industry
C	Competition between teams within a project
D	Lack of business process integration or shared activities between project phases
E	Knowledge from design phase is not readily available at construction phase
F	Lack of capture, documentation and maintenance of knowledge from previous phase
G	Difficult to find the relevant knowledge even if it exists
H	Lack of integration of activities across the lifecycle of projects
I	Difficult to understand and interpret previously captured knowledge

Even though the research was focused on transition from design to construction, findings indicated the inseparability of processes of the lifecycle phases. This means that while focus can be made on particular phases, an integrated view should not be neglected. This research also recognised another approach to *bidirectional* (i.e., backward and forward) information and knowledge flow exists between project phases and should be factored in mitigating the loss of knowledge.

This integrated view, with *bidirectional flow* of information and knowledge, is necessary in enabling and facilitating endeavours to avoid or mitigate loss of knowledge. For example, at *design phase*, information and knowledge may be required from the *construction phase* to execute design related activities; similarly, at the construction phase, design information and knowledge will be required as illustrated in Figure 10. This bidirectional flow can be propagated across the lifecycle phases of construction projects as well as from one project to another.

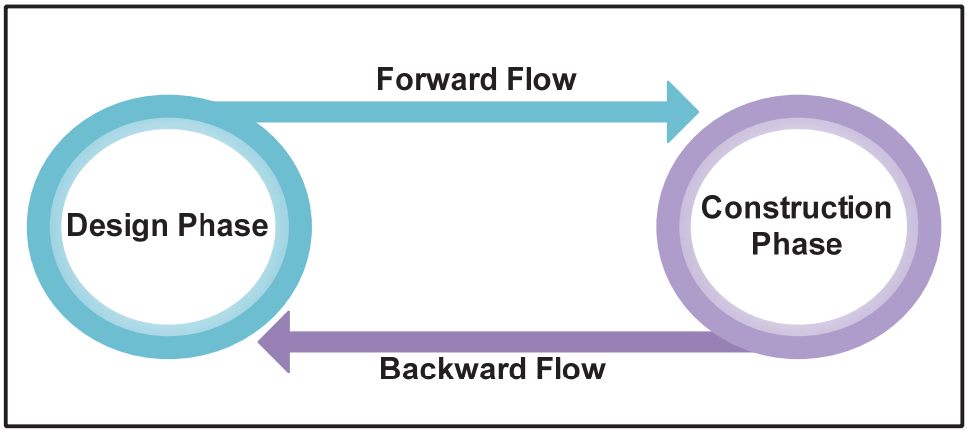

Figure 10: Bidirectional Information and Knowledge Flow Between Phases

5 Conclusions and Recommendations

5.1 Research Summary

This research was aimed at identifying KM needs during the processes of designing, constructing and managing buildings. Data and information obtained from the interviews and workshop were analysed which formed the basis for

drawing conclusions and recommendations. In order to achieve the aim of the research, the following objectives were specified:

- To describe and investigate the flow of knowledge within a construction project.
- To identify the losses of knowledge that occurs at the transition between various phases (with emphasis on the transition from '*design to construction*').
- To propose KM solutions to minimise those losses.

Each of these objectives is discussed below summarising the detailed activities carried out and the results achieved from them.

Objective 1:

- ***To describe and investigate the flow of knowledge within a construction project.***

This objective was achieved through a review of literature of information and knowledge management within the construction industry. This review included how information and knowledge are created in a project environment, their sources, characteristics and the different forms in which they can be represented. The review also considered the different stakeholders of a project and their information and knowledge needs during the conduct of their activities. The mechanisms and channels of information and knowledge sharing and exchange; including distribution to all parties was examined as well as the impact of those media to the flow.

The review was able to highlight the current practice of knowledge management and its importance in the design, construction, operations and maintenance of buildings. This indicated the use of manual and paper-based approaches to managing construction information and knowledge which are generally held in different locations, in different media and accessed and utilised by different people. Knowledge could also be held tacitly which is crucial in the design and construction processes. It was identified that the efficient flow of knowledge between all stakeholders across all project phases as a collaborative endeavour is relevant to avoid or minimise loss of knowledge.

Objective 2:

- ***To identify the losses of knowledge that occur at the transition between various phases (with emphasis on the transition from 'design to construction')***

The review of the knowledge management literature revealed how knowledge flows

in a construction project which has an effect on the loss of knowledge. Consequently, it was then significant to identify '*what goes well and what does not*' during that flow. As a result, the flow of knowledge was examined in order to identify the causes of loss of knowledge and to define approaches for their prevention.

Industrial study in the form of interviews and a workshop with construction practitioners and other stakeholders was conducted which helped reveal the practicalities of knowledge flow and enabled an in-depth review of the process as currently applied to construction projects. The industrial study focused on the identification of the loss of knowledge during the transition between various project phases.

Firstly, the mechanisms and tools used for information and knowledge storage were examined; secondly, the tools used in the process of knowledge communication and sharing; thirdly, the activities of each phase (focusing on design to construction) were reviewed and their information and knowledge needs, detailing their interaction (including interaction of the different disciplines) and how that impacts on loss of knowledge; and finally, various factors were identified that can contribute to the loss of knowledge. Out of those factors, four were identified as the major contributing factors as discussed in section 4.2.4.

Objective 3:

- ***To propose KM solutions to minimise those losses.***

Based on the review of the flow of knowledge and the identification of the losses of knowledge during the transition between project phases, knowledge management solutions are proposed to avoid or minimise those losses. The solutions are: a knowledge retention framework, knowledge management tool to implement the framework, integration of business processes across all phases and tools for synchronous communication. These solutions are discussed in detail in section 5.4. These solutions are identified based on the understanding that Information in a construction project environment keeps changing throughout all phases. Therefore distributed and shared knowledge through collaborative and integrated processes in a project team is prudent and can facilitate towards overcoming the problem of loss of knowledge in construction projects.

5.2 Conclusions

The research reported in this report examined knowledge management needs in construction projects in order to identify

loss of knowledge in transition between project phases and to define solutions. Subsequent to the conduct of the research, the following conclusions are formulated:

- Information and knowledge are regarded as critical resource in the transition between various phases of a construction project.
- Information and knowledge management in construction projects is paper-intensive and this does not prove to contribute to efficient and effective information and knowledge flow between the multiple stakeholders and across the various phases.
- There is a lack of integration between the processes of the various project phases and this creates fragmentation which makes it more difficult to retain knowledge during transitions from one project phase to another.
- *A bidirectional flow* of information and knowledge is necessary in enabling and facilitating endeavours to avoid or mitigate loss of knowledge.
- Several factors contribute to the loss of knowledge with four as major contributors as discussed in section 4.2.4. These are: lack of business process integration and shared activities between project phases, lack of adequate capture, documentation and maintenance of knowledge from previous phase, the fragmented nature of the construction industry, and difficulties to find the relevant knowledge even if it exists.
- An efficient knowledge retention approach within the general knowledge management initiatives would ensure that potential losses of knowledge are identified and measures taken to prevent them from occurring.
- Findings indicate that different disciplines require different sets of knowledge to perform their activities; and they also prefer to use particular tools for knowledge communication and sharing.
- Any knowledge management solution defined should factor the social interaction of the people involved in the construction project.

5.3 Limitations

This research identified the following limitations which can limit the generalisation of the results:

- Both the interviews and workshop involved a limited number of practitioners and stakeholders from a relatively small project and are not generally representative of the

construction industry. However, even being a relatively small project, the results illustrate the complexity of knowledge management and larger projects might be even more complex.

- The research focused primarily on the transition from design to construction and it also appeared that participants in the workshop were at the time involved on a project that was at that particular transition. It would have been relevant to examine all other transitions in-between the various phases.

5.4 Recommendations

From the research conducted, the following recommendations are made to retain knowledge and avoid or mitigate against its loss:

Recommendations
▪ *Knowledge retention framework*
▪ *Knowledge management tool*
▪ *Integration of business processes across all phases*

5.4.1 Knowledge retention framework

A *knowledge retention framework* needs to be established. This framework should be *process-oriented* based on systems thinking and should incorporate the dynamics of social interaction in construction projects. The framework should be developed in the first phase of the process to avoid or minimise loss of knowledge upon which both the KM tool and the integration of business processes will be based as shown in Figure 11. It must also specify an integrated approach to construction process execution between stakeholders and across all phases of a project. This will help streamline business processes and people thus contributing towards simpler access to and sharing of knowledge which are constituents to knowledge retention.

5.4.2 Knowledge management tool

Process management and integrated IT Tools for work processes can play a major role in the successful implementation of any KM strategies. It is therefore being recommended that in order to facilitate and improve the mechanisms to avoid or minimise loss of knowledge, KM technologies (i.e., IT-base tools) should be designed and developed for each different phase of a project thereby meeting their demand. This is relevant because of the nature of the activities of the individual projects phases which requires different tools. For example, KM tools that may be required at preparation will be different from those of design phase. This development should take an integrated

approach in order to facilitate their interoperability.

These tools should be based on the framework and should accommodate all its features particularly the social interaction of the people. No matter what types of tools are developed, they should feature *email* as an integral component because it has emerged as a desired tool for information and knowledge communication and sharing.

5.4.3 *Integration of business processes across all phases*

Construction projects require cross-functional operating environments and processes in order for production to be successful. The fragmentation between project phases creates more difficulties of retaining knowledge during transitions from one project phase to another. Consequently, there is the need to bridge the disintegration in order to smoothen that transition and help in knowledge retention.

This research recommends '*bridging the gap*' by integrating the construction business processes of the phases to enable seamless flow of information and access to knowledge. This integration can be powered through process-orientation. This will innovate a mechanism whereby information and knowledge can be captured real-time whilst performing those processes. The integration can also make use of the KM tool which is a facilitator of the process.

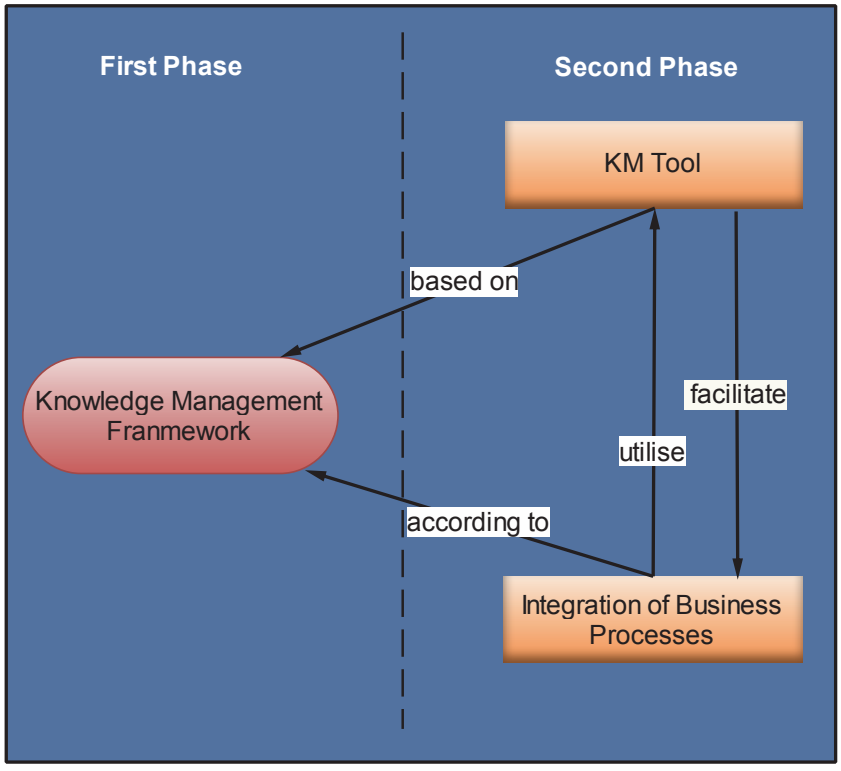

Figure 11: Recommendation Roadmap for Prevention of Loss of Knowledge

Acknowledgements

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References

Al-Ghassani, A. H. et al. (2005). "Tools and Techniques for Knowledge Management", In: Anumba, C. J., et al (eds). (2005). *Knowledge Management in Construction,* 83-102. Oxford: Blackwell Publishing.

Anumba, C. J., Egbu, C. and Carrillo, P.(eds) (2005). *"Knowledge Management in Construction",* Oxford: Blackwell Publishing

Anumba, C. J., Ugwu, O. O., Newnham, L. and Thorpe, A. (2002). "Collaborative design of structures using intelligent agents", *Automation in Construction,* Vol. 11(1), pp. 89-103.

Austin, S. A., Baldwin, A. N., Li, B. and Waskett, P. R. (2000). "Analytical Design Planning Technique (ADePT): a dependency structure matrix tool to schedule the building design process", *Construction Management and Economics,* Vol. 18(2), pp. 173-182.

Boyatzis, R. E. (1998). *"Transforming qualitative information : thematic analysis and code development".* Thousand Oaks, Calif. ; London: Sage.

Bryman, A. (2008). *"Social Research Methods".* 3rd (ed.) Oxford: Oxford University Press.

Carrillo, P. M., Robinson, H. S., Anumba, C. J. and Ghassani, A. M. (2003a). "IMPaKT: A Framework for Linking Knowledge Managementto Business Performance", *Electronic Journal of Knowledge Management,* Vol. 1(1), pp. 1-12.

Carrillo, P. M., Robinson, H. S. and Hartman, F. (2003b). "Knowledge Management Strategies: Learning from other sectors", In: Molenaar, K. R. and Chinowsky, P. S.,*Proceedings of the 2003 Construction Research Congress,* March 19 - 21, ASCE, pp. CD-ROM,

Demian, P. and Fruchter, R. (2006). "Methodology for Usability Evaluation of Corporate Memory Design Reuse Systems", *Journal of Computing in Civil Engineering,* Vol. 20(6), pp. 377-389.

Eastman, C., Teicholz, P., Sacks, R. and Liston, K. (2008). *"BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors".* New Jersey: John Wiley & Sons.

Emmitt, S. and Gorse, C. A. (2007). *"Communication in Construction Teams".* London: Taylor & Francis.

Fellows, R. and Liu, A. (2008). *"Research Methods for Construction".* 3rd (ed.) Oxford: Wiley-Blackwell.

Fruchter, R. and Demian, P. (2005). "Corporate Memory", In: Anumba, C. J., et al (eds). (2005). *Knowledge Management in Construction,* 170-194. Oxford: Blackwell Publishing.

Fruchter, R. and Demian, P. (2002). "CoMem: Designing an Interaction Experience for Reuse of Rich Contextual Knowledge from a Corporate Memory", *Artificial Intelligence in Engineering Design, Analysis and Manufacturing. AIEDAM Special Issue: Human-computer Interaction in Engineering Contexts,* Vol. 16(3), pp. 127-147.

Gibson, W. J. and Brown, A. (2009). *"Working with Qualitative Data".* London: Sage.

Hasan, H. and Gould, E. (2003). "Activity-based Knowledge Management Systems", *Journal of Information and Knowledge Management,* Vol. 2(2), pp. 107-115.

Heisig, P. (2001). "Business Process Oriented Knowledge Management", In: Mertins, K., et al (eds). (2001). *Knowledge Management: Best Practices in Europe,* 13-36. New York: Springer.

Kazi, A. S.(ed) (2005). *"Knowledge Management in the Construction Industry: A Socio-Technical Perspective",* London: Idea Group

Latham, M. (2005). "Foreword", In: Anumba, C. J., et al (eds). (2005). *Knowledge Management in Construction,* vii-viii. Oxford: Blackwell Publishing.

Lee, C. C. and Egbu, C. (2008). "Client requirements and project team knowledge in refurbishment projects", In: Smyth, H. and Pryke, S. (eds). (2008). *Collaborative Relationships in Construction: developing frameworks and networks,* 59-77. Oxford: Wiley-Blackwell.

Leistner, F. (2010). *"Mastering Organizational Knowledge Flow: How to Make Knowledge Sharing Work".* Hoboken, N.J.: John Wiley and Sons.

Liebowitz, J. (2009). *"Knowledge Retention: Strategies and Solutions".* London: CRC Press.

Nonaka, I. and Takeuchi, H. (1995). *"The Knowledge-creating company: How Japanese Companies Create the Dynamics of Innovation".* Oxford: Oxford University Press.

Otter, A. and Emmitt, S. (2007). "Exploring effectiveness of team communication: Balancing synchronous and asynchronous communication in design teams", *Engineering, Construction and Architectural Management,* Vol. 14(5), pp. 408-419.

Ruikar, K. D., Koskela, L. and Sexton, M. G. (2009). "Communities of Practice in Construction Case Study Organizations: Questions & Insights", *Construction Innovation,* Vol. 9(4), pp. 434-448.

Ruikar, K., Anumba, C. J. and Egbu, C. (2007). "Integrated Use of Technologies and Techniques for Construction Knowledge Management", *Knowledge Management Research and Practice,* Vol. 5(4), pp. 297-311.

Swenden, W. (2006). *"Federalism and Regionalism in Western Europe : A Comparative and Thematic Analysis".* Basingstoke: Palgrave Macmillan.

Tserng, H. P. and Lin, Y. (2004). "Developing an activity-based knowledge management system for contractors", *Automation in Construction,* Vol. 13(6), pp. 781-802.

Appendices

Appendix A: Interview Plan

Lost in Transition - Interviews

Questionnaire

This study aims to investigate knowledge management problems in construction projects. Specifically, it concentrates on the loss of knowledge during transition from one project phase to another.

Please be assured that the information you provide in this questionnaire will be treated with due care and shall be used solely for the purpose of the research. No individual or organisation will be identified from it.

Interviewee Role and Responsibility: ……

Company:…….

Date:…….

1. What type of project are you involved in?

2. What kind of project procurement system is used in your project?

3. Do you regard design information as a critical resource in the transition between design and construction? Why?

1. Which of the following best describes the stage of knowledge management practice in your organisation?

   a) None b) Developing

   c) Growing d) Maturity e) Declining

4. During the conduct of your activities, do you apply knowledge management practices within your project processes?

5. If yes (Q5), what tools/techniques/technologies are used? And Why?

6. During design, what type of information do you require from other phases? E.g. construction phase.

7. During construction, what type of information do you require from other phases? E.g. design phase.

8. What is the source of such knowledge and where does it reside?

9. What organisational processes are in place to acquire this knowledge?

10. In instances of uncertainty during design or construction, how do you get to a decision on such uncertainty?

11. How do you make judgement on such decision?

12. How do you capture and utilise knowledge between design and construction?

13. What worked well during the capture and use?

14. What did not go well during the capture and use?

15. What difficulties do you experienced in the capture and use?

16. How do you share information generated at each phase throughout the project?

17. When knowledge is generated and utilised during a particular phase, is there any mechanism to maintain it for future use?

18. What measures would you recommend to improve knowledge retention?

19. To what extent do you agree the following factors contribute towards the loss of knowledge between project phases?
A) Agree B) Disagree C) Agree strongly D) Disagree strongly
E) Don't know

Please also indicate your top three most critical factors.

	Factors	A	B	C	D	E
i	Lack of KM initiative and practices within your organisations					
ii	Fragmented nature of the construction industry					
iii	Competition between project teams					
iv	Lack of business process integration between project phases					
v	Knowledge from design phase is not readily available in construction phase					
vi	Difficult to find the relevant knowledge even if it exists					
vii	Lack of capture, documentation and maintenance of knowledge from previous phase					
viii	Lack of collaboration between teams operating at different phases					
ix	Lack of shared activities between project phases					
x	Lack on integration of business activities across the lifecycle of projects					
xi	Difficult to understand and interpret previously captured knowledge					

Appendix B: Workshop Questionnaire

Lost in Transition Workshop Questionnaire

2. Which of the following best describes your role?
   - I. Client
   - II. Architect
   - III. Structural Engineer
   - IV. Mechanical Engineer
   - V. Contractor
   - VI. Sub-contractor
   - VII. Facilities Manager
   - VIII. Project Manager
   - IX. Others
3. Which of the following best describes the stage of knowledge management practice in your organisation?
   - I. None
   - II. Developing
   - III. Growing
   - IV. Maturity
   - V. Declining
4. Which two project transition phases require the most focus on knowledge management? (Rank in order of preference with favourite first)
   - I. Briefing to design
   - II. Design to construction
   - III. Construction to operation
   - IV. Operation to end-of-life
5. Which of the two best describes the current communication practice in your projects?

1. 

Over the wall

2. 

Collaborate

Note: Images adopted for demonstration purposes only

6. Which two tools/techniques do you use the most when sharing knowledge? (Rank in order of preference with favourite first)
   - I. Intranet
   - II. Email
   - III. Technical group/interest group/communities of practice

IV. Meetings
V. Document management system
VI. Project extranet

7. Which of these is your preferred medium for construction information and knowledge documentation?
   I. Paper-based documents
   II. Digital documents
   III. Databases
   IV. Email
8. To what extent do you agree that 'Lack of KM initiative and practices within your organisation' contributes to loss of knowledge?
   I. Agree Strongly
   II. Agree
   III. Don't know
   IV. Disagree
   V. Disagree Strongly
9. To what extent do you agree that 'Fragmented nature of the construction industry' contributes to loss of knowledge?
   I. Agree Strongly
   II. Agree
   III. Don't know
   IV. Disagree
   V. Disagree Strongly
10. To what extent do you agree that 'Competition between teams within a project' restricts knowledge sharing?
   I. Agree Strongly
   II. Agree
   III. Don't know
   IV. Disagree
   V. Disagree Strongly
11. To what extent do you agree that 'Lack of business process integration or shared activities between project phases' contributes to loss of knowledge?
   I. Agree Strongly
   II. Agree
   III. Don't know
   IV. Disagree
   V. Disagree Strongly
12. To what extent do you agree that 'Knowledge from design phase is not readily available at construction phase'?
   I. Agree Strongly
   II. Agree
   III. Don't know
   IV. Disagree
   V. Disagree Strongly

13. To what extent do you agree that 'Lack of capture, documentation and maintenance of knowledge from previous phase' contributes to loss of knowledge?
    I. Agree Strongly
    II. Agree
    III. Don't know
    IV. Disagree
    V. Disagree Strongly
14. To what extent do you agree that 'Difficulty to find the relevant knowledge even if it exists' contributes to loss of knowledge?
    I. Agree Strongly
    II. Agree
    III. Don't know
    IV. Disagree
    V. Disagree Strongly
15. To what extent do you agree that 'Lack of integration of activities across the lifecycle of projects' contributes to loss of knowledge?
    I. Agree Strongly
    II. Agree
    III. Don't know
    IV. Disagree
    V. Disagree Strongly
16. To what extent do you agree that 'Difficulty to understand and interpret previously captured knowledge' contributes to loss of knowledge?
    I. Agree Strongly
    II. Agree
    III. Don't know
    IV. Disagree
    V. Disagree Strongly
17. Select your top three contributors to loss of knowledge? (Rank in order of preference with favourite first)
    I. Lack of KM initiative and practices within your organisation
    II. Fragmented nature of the construction industry
    III. Competition between teams within a project
    IV. Lack of business process integration or shared activities between project phases
    V. Knowledge from design phase is not readily available at construction phase
    VI. Lack of capture, documentation and maintenance of knowledge from previous phase
    VII. Difficulty to find the relevant knowledge even if it exists
    VIII. Lack of integration of activities across the lifecycle of projects
    IX. Difficulty to understand and interpret previously captured knowledge-