

# CONCEPTUAL FRAMEWORK FOR LIVE CAPTURE AND REUSE OF PROJECT KNOWLEDGE

John M. Kamara<sup>1</sup>, Chimay J. Anumba<sup>2</sup>, Patricia M. Carrillo<sup>2</sup> and Nasreddine (Dino) Bouchlaghem<sup>2</sup>

<sup>1</sup>*School of Architecture, Planning & Landscape, University of Newcastle upon Tyne, UK*

[j.m.kamara@ncl.ac.uk](mailto:j.m.kamara@ncl.ac.uk)

<sup>2</sup>*Department of Civil & Building Engineering, Loughborough University, UK*

[c.j.anumba@lboro.ac.uk](mailto:c.j.anumba@lboro.ac.uk); [p.m.carrillo@lboro.ac.uk](mailto:p.m.carrillo@lboro.ac.uk); [n.m.bouchlaghem@lboro.ac.uk](mailto:n.m.bouchlaghem@lboro.ac.uk)

## SUMMARY

The concept of knowledge management (KM) is now familiar to the construction industry, and various attempts are being made to develop tools and techniques for the effective management of knowledge in the industry. This paper addresses the 'live' capture of construction project knowledge, which is as yet, an elusive goal in KM efforts. It describes an approach to achieve this using a combination of techniques and tools including learning histories, collaborative learning, project extranets and workflow management. This proposed methodology also specifies the incorporation of a 'project knowledge file' which will form the basis of knowledge capture during the execution of a project, an integrated workflow system and a project knowledge manager. The intention is to ensure the currency and relevance of the knowledge captured, prevent the 're-invention of the wheel', and facilitate innovation, increased agility, better teamwork and supply chain integration, and improved project performance.

## INTRODUCTION

Knowledge management (KM) is now a familiar concept in the architecture, engineering, construction (AEC) industry, and the effective management of project knowledge, it is acknowledged, is necessary for improved performance. KM deals with the organizational optimization of knowledge through the use of various technologies, tools and processes to achieve set goals (Kamara et al. 2002a). In the case of the AEC industry, these goals include improved efficiency and innovation in project delivery. KM is also seen as a means to prevent the 'reinvention-of-the-wheel' for every new project.

This paper focuses on the tactical issue of knowledge capture and reuse on construction projects, which involve a network of multi-disciplinary organizations. Such projects are often unique in macro terms (e.g. context, site, client requirements, etc.) but similar in a micro context; thus the lessons learnt during their execution should be reused in other projects. A proposed research that is aimed at developing a methodology for the live capture and reuse of project knowledge is described. This research was designed to overcome the limitations in current practice for the capture of project knowledge, and to contribute to the growing body of research on KM in construction. Current practice for knowledge capture and reuse, and research initiatives for KM are reviewed. The paper then describes the proposed methodology for live knowledge capture and concludes with suggestions of how this might be implemented in practice, and further work that is required in this area.

## KNOWLEDGE MANAGEMENT IN CONSTRUCTION

The management of knowledge in construction is at two levels: management of project knowledge, and KM within individual firms. KM practice in construction is mostly informal and people-centred, although there is a growing trend towards the development of 'formal' KM strategies within construction firms (McConalogue, 1999, Kamara et al. 2002a). Other strategies include the development of standard operating procedures, best practice guides, and codes of practice. These are mostly used within individual firms, however, since the construction industry revolves around projects, more will be said about the capture and reuse of project knowledge.



## Capture and reuse of project knowledge

The most common approach used in the industry to capture the learning from projects is the post-project evaluation (Orange et al. 1999). This is usually conducted individually by participating organizations to a project. Post project evaluation can be useful in consolidating the learning of people involved in the project under review, but there are indications that current practice does not provide an effective framework for the capture and reuse of learning. A common problem is that of insufficient time for post-project evaluation to be conducted effectively (if conducted at all), as relevant personnel would have moved to other projects (Orange et al, 1999). Furthermore, it does not allow the current project to be improved by incorporating the lessons being learnt as the project progresses. There is also the problem of loss of important information or insights due to the time lapse in capturing the learning. Moreover, in consolidating the learning of people involved, post project evaluation is a not very effective mechanism for the transfer of knowledge to non-project participants. It is also limited in scope, in that the perspective is that of members within only one of the participating organizations to the project.

The reliance on people is based on the assumption that the knowledge acquired from one project can be transferred by that individual when s/he is reassigned to another project. The use of long-standing (framework) agreements (e.g. within a partnering contract) with suppliers to maintain continuity in the delivery of projects for a specific client is also designed to ensure that the learning by individuals and firms is reused on future projects. However the reliance on people, even within a framework agreement, makes organisations vulnerable when there is a high staff turnover. The use of framework agreements also cannot guarantee that the learning of individual firms participating in the agreement is shared to other participants for the benefit of the project, since these firms can be in competition elsewhere (e.g. on other projects) and may not want to divulge 'secrets' that might weaken their competitive advantage.

## Knowledge management research in construction

The apparent limitations in industry practice and the acknowledged importance of KM have led to various efforts to improve KM in construction. Within the UK, these include the following projects:

- Cross-sectoral LEarning in the Virtual entERprise (CLEVER). This was a twenty-month project based at Loughborough University and was completed in 2001. It focused on the development of a framework for the transfer of knowledge in a multi-project environment in construction. The framework developed assists construction firms in selecting an appropriate strategy for the transfer of knowledge that is appropriate to their organisational and cultural contexts (Kamara et al., 2002b).
- Knowledge Management for Improved Business Performance (KnowBiz). This is a three year project based at Loughborough University with completion scheduled for May 2003. It is aimed at establishing the link between knowledge management and business performance in construction firms (Carrillo and Anumba, 2000).
- Knowledge and Learning In CONstruction (KLICON). This was a two-year project based at UMIST and completed in 2001. The project focused on the role of IT in capturing and managing knowledge for organisational learning on construction projects (McCarthy et al., 2000).
- Creating, Sustaining and Disseminating Knowledge for Sustainable Construction: Tools, Methods and Architecture (CSanD). This is a three-year project which commenced in June 2001 and conducted jointly by Loughborough University, Salford University and London School of Economics. It aims to provide mechanisms for ensuring knowledge pertaining to sustainability is captured and distributed in a structured manner (CSanD, 2001).
- e-COGNOS. This is a two-year EU-funded project that commenced in July 2001 involving construction and IT organizations from France, UK, Germany and Finland. It aims to specify and develop an open model-based infrastructure and a set of tools that promote consistent knowledge management within collaborative construction environments (e-COGNOS, 2002).

Other initiatives in the US (Stanford University) focused on the development of a project memory capture system for design evolution capture, visualisation and reuse in support of multi-disciplinary collaborative teamwork (Reiner and Fruchter, 2000). In Europe, work at Dresden University of

Technology in Germany focused on the retrieval of explicit project knowledge from heterogeneous documents (Scherer and Reul, 2000).

The initiatives described above do suggest that although much is being done in the area of KM in construction, the core issue of the live capture of knowledge on construction projects is still not being addressed. The closest to this goal is the work at Stanford (Reiner and Fruchter, 2000), which focuses on the knowledge capture during the design evolution stage, but does not cover the entire project.

## **Challenges for knowledge capture and reuse**

To overcome the limitations in current industry practice on the capture and reuse of knowledge, it is necessary that learning from a project is captured *while it is being executed*, and presented in a format that will facilitate its reuse during and after the project, and in other contexts such as professional education and training of new construction staff. The 'live' capture and representation of project knowledge will:

1. Facilitate the reuse of the collective learning on a project by individual firms and teams involved in its delivery;
2. Provide knowledge that can be utilized at the operational and maintenance stages of the asset's lifecycle; and
3. Involve members of the supply chain in a collaborative effort to capture learning in tandem with project implementation, irrespective of the contract type used to procure the project from the basis for both ongoing and post-project evaluation.

The 'live' capture and reuse of construction project knowledge poses a number of questions:

1. What knowledge from a project is reusable in other projects?
2. How can this knowledge be captured (during and after project implementation) in a cost-effective way, given the temporary nature of construction projects, and given the various facets (e.g. organisational, human and technology issues) that need to be considered?
3. How can project knowledge be captured without causing unnecessary knowledge overload for project participants who already have to cope with huge amounts of project information?
4. In what ways can captured knowledge be made available for reuse during (and after) project execution?

A strategy for live knowledge capture that addresses the questions above is presented.

## **STRATEGY FOR LIVE KNOWLEDGE CAPTURE**

The development of an appropriate methodology for the live capture of construction project involves the use of both 'soft' (i.e. organisational, cultural and people issues) and 'hard' (information and communication technologies – ICTs) concepts and tools. It also involves the following:

1. An investigation of the current practice of knowledge capture and identification of the requirements for knowledge reuse by end users of project knowledge. This will ensure that the right kind of knowledge is captured to avoid knowledge overload;
2. An exploration of the concepts and techniques that would facilitate the 'live' capture of reusable project knowledge in the construction industry;
3. The development of a methodology for the live capture of reusable knowledge on construction projects; and
4. The testing of the methodology on a web-hosted project environment (for easy access to all project participants) and evaluate its effectiveness using live projects.

## **'Soft' concepts for live knowledge capture**

These include the existing concepts of 'collaborative learning (CL)' and 'learning histories (LH)', which will be adopted for use within a construction project context. These concepts will play a key part in the development of the 'methodology' for live knowledge capture.

Collaborative learning is a business practice that is aimed at discovering explicit and tacit collaboration tools, processes, and knowledge, experimenting with them and creating new knowledge from them (Digenti, 1999). It employs methods and approaches that emerge from the present situation and allow organizations to move across boundaries fluidly and to assure that the learning that takes place is one group (e.g. a project) is transferred back to the organization. This is quite appropriate to the context of construction projects, where a network of organizations is involved in delivering projects. This concept can therefore be adapted to facilitate the transfer and reuse of collective learning to the individual firms involved in implementing it.

A learning history is a process, originally developed at the Massachusetts Institute of Technology (MIT), for capturing usable knowledge from an extended experience of a team and transferring that knowledge to another team that may operate in a different context (Kleiner and Roth, 1997; Dixon, 2000). Construction projects and the teams that implement them are unique, but the structure of teams, processes, tools, skills, etc. used in these projects are similar, and provide the opportunity for the reuse of knowledge. Therefore, using the concept of a 'learning history', the learning of one team (from critical events on a project) can serve as a catalyst to a similar team to deal with issues in a different context.

## **'Hard' technologies for live knowledge capture**

The 'hard' tools for knowledge capture include available ICT applications that are currently being used in the construction industry, particularly project extranets, workflow management tools and other groupware applications for collaborative working.

Project extranets (or project websites) are "dedicated web hosted 'collaboration and information spaces' for the AEC [architecture, engineering and construction] industry that support design and construction teams" (Augenbroe et al 2001). Extranets are hosted by a growing number of third-party organisations (application service providers – ASPs) which include Architec Ltd., 4Projects, Bidcom, BIW Technologies, Buzzsaw and BuildOnline (Kamara and Anumba, 2002). Project extranets utilise client-server technology and a web browser is usually all that is required to allow distributed project team members to share, view and comment on project-relevant information. The growing use of extranets in the delivery of construction projects, and the collaborative facilities they provide (CPN, 2002), make them suitable as a platform on which a methodology for live knowledge capture can be mounted. The proposed use of web-based technology will address the constraints of distributed teams, and would facilitate contributions from various members of a project without the need to meet in one location. Furthermore, the widespread availability and use of the Internet would make it possible for most firms in the supply chain to be able to use the tool. However, because of the current limitations of extranets (e.g. being purely document-centric with limited facilities for workflow) other tools and technologies (e.g. workflow modelling and automation tools, web-server push technologies, etc.) will be utilised.

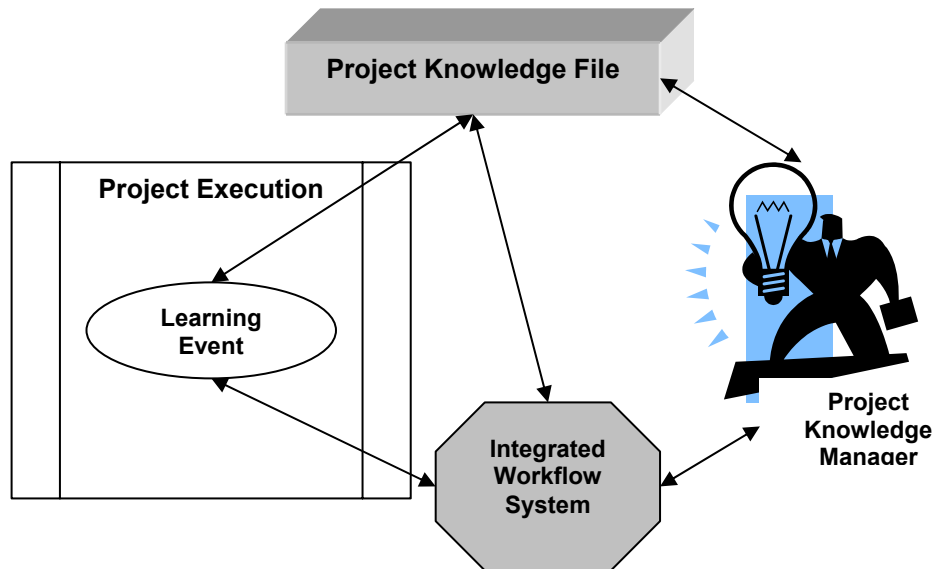
A proposed framework for knowledge capture that incorporates both 'soft' concepts and 'hard' technologies is now described.

## **CONCEPTUAL FRAMEWORK FOR LIVE KNOWLEDGE CAPTURE**

The real-time capture of project knowledge can be effected through the following: a project knowledge file, an integrated workflow system, and a project knowledge manager. However, before these components are described, an overview of procedure for knowledge capture will be presented.

## Overview of knowledge capture procedure

Figure 1 shows an overview of the knowledge capture procedure. During the course of a construction project, learning occurs not only from many critical events but also from the normal day-to-day operations. This learning can be about the facility being constructed, the project process or the participants involved in its execution. Within the knowledge capture procedure, the structure of how learning is captured is determined beforehand in the project knowledge file. When a learning event occurs, the integrated workflow system is triggered and this sets in motion a flow of actions to capture the learning at a particular point in time. The learning is compiled and edited for reuse within the current project, or in subsequent projects.



**Figure 1** Overview of knowledge capture system

### Project knowledge file

The 'project knowledge file' (PKF) is similar to the Health and Safety File (HSF) under the Construction (Design and Management) (CDM) Regulations in the UK. "The health and safety file is a record of information for the client which focuses on health and safety" (HSE, 1997). The detailed information collected depends on the nature and size of the project, but it is used to "alert those who are responsible for the structure of the key health and safety risks that will need to be dealt with during subsequent maintenance, repair and construction work" (HSE, 1997).

Similar to the HSF, the Project Knowledge File (PKF) will contain information relating to the 'project knowledge', but will focus on knowledge that can be reused both during the execution (e.g. in subsequent phases), and after the completion of the project. The kind of knowledge to be captured and the format and contents of the PKF will be determined through detailed research into reusable project knowledge, but the goal will be to develop an ongoing 'learning history' for the project within a collaborative environment. The PKF is agreed on at the onset of a project and all parties are required to contribute to its compilation. The PKF should be managed by a designated Project Knowledge Manager (similar to the role of a Planning Supervisor under the CDM regulations), but depending on the size and nature of the project, this role can be combined with that of the project manager.

### Integrated workflow system

The role of the integrated workflow system (IWS) is to implement the PKF in real-time. That is, to facilitate the compilation of the learning history for the project during its execution, in accordance with the parameters set out in the PKF. A generic model for the workflow will be developed following research into the format and contents of the PKF, but it should be customisable to take into account variations in the PKF. The IWS is triggered when a 'learning event' (i.e. an activity or event from which reusable knowledge can be captured) takes place. This can be, for example, problems and how they

were solved, innovations, breakthroughs or the normal day-to-day operations of a project. When such events occur, the IWS will request the relevant participants (in accordance with the agreement set out in the PKF) to contribute their views on how various issues were dealt with. A compilation of these different perspectives will form part of the 'learning history' at particular stages of a project, which can either be reused at subsequent phases, or at the end of a project. The trigger for the IWS can either be automated, done manually by a project knowledge manager, or a combination of both manual and automated systems. An automated trigger requires data and text mining capabilities or other means of detecting, say within a project extranet, when certain events occur. In both automated and manual triggers, server 'push' technologies will be utilised to ensure that the required prompt is pushed to relevant participants. The IWS should also have filtering capabilities to ensure that only the relevant learning is captured to prevent knowledge/information overload. The IWS can be integrated with existing project extranets or can be developed as a separate application that is compatible with extranets.

### **Project knowledge manager**

This is a role (as opposed to a particular individual) that will be charged with developing and managing the Project Knowledge File (PKF) and the Integrated Workflow System (IWS). A person or persons occupying this role will need to be familiar with the principle of learning histories and how they are developed.

## **DISCUSSION**

The proposed framework for the live capture of project knowledge addresses a key problem in the construction industry, which had hitherto not been adequately considered. This was due to the absence of support technologies to facilitate the real-time capture of project knowledge, hence the emphasis on post-project reviews and the reliance on people. However, with the increasing use of web-hosted project extranets, there is now the possibility to make use of this, and other related, technology to develop a suitable medium for the live capture and reuse of project knowledge. This proposed framework will also be a timely addition to current efforts to improve the functionality of extranets (which are mainly document repositories) by incorporating features such as workflow and process management.

The live capture methodology adopts an innovative approach, which will constitute a step change in knowledge management in construction. Its novelty is in the use of both 'soft' and 'hard' strategies to ensure that a more 'rounded' approach to knowledge capture and reuse is achieved. The adaptation of concepts such as 'collaborative learning' and 'learning histories', which had hitherto not been used in the construction industry, will bring fresh ideas to existing efforts to address the knowledge management issues in the industry.

The combined approach of 'soft' and 'hard' concepts is not only because of its relevance to the objectives of the research. Lessons from past research initiatives also suggest that the combined approach of 'soft' and 'hard' is the most sensible approach to be adopted. Previous work on knowledge management focused on the delivery of technological solutions (Carrillo et al. 2000), probably because of the growth in knowledge based expert systems in the eighties and early nineties. However, it is now recognised that good knowledge management does not result from the implementation of information systems alone (Davenport, 1997; Stewart, 1997). Therefore approaches that are purely based on information technology (IT) are bound to be less than successful: organisational and people issues, which are not readily solved by IT systems, would need to be resolved (Tiwana, 2000). On the other hand, approaches that exclusively focus on organisational and cultural issues would not reap the benefits derived from the use of IT, especially in the context of distributed teams that are the norm in construction (Anumba et al. 2000). For example, in the B-HIVE (Building a High Value Construction Environment) research project, which developed a Cross Organisational Learning Approach (COLA) for learning and knowledge generation through reflection and discussion within a partnering context, it was concluded that the use of IT (e.g. a project extranet), would enhance the usefulness of the COLA system (Orange et al. 1999). Thus a combined approach will deliver a more complete solution that incorporates 'soft' issues with 'hard' technological issues.

The live knowledge capture system, through ensuring the *currency* and *relevance* of the knowledge captured, will have a significant impact on the overall construction process:

1. Construction supply chains will benefit through the shared experiences that are captured as part of the learning on key events (e.g. problems, breakthroughs, change orders, etc.). The benefits to this group are both short- and long-term. Short-term in the sense that project teams would be enabled to manage better the subsequent phases of a project (through the capture and transfer of learning from a previous phase). Long-term because it will increase their capacity to better plan future projects and their ability to collaborate better with other organisations. Furthermore, learning from past projects can be used to train new employees and project managers.
2. Other project teams can use the learning captured from previous/similar projects to deal with problems; reflection on previous learning can also trigger innovative thinking (to think about issues that might be relevant to their project).
3. Client organisations will benefit from enriched knowledge about the development and construction of their assets. This will contribute to the effective management of facilities and the commissioning of other projects. In the longer term, clients will benefit from the increased certainty with which construction firms can predict project outcomes.
4. Project staff and students of project/construction management and the institutions providing such courses/training will also benefit through the use of captured project knowledge as case study material.
5. Improved supply chain management, as team members would work more collaboratively and share the lessons learnt on construction projects.
6. The construction industry will benefit from an enhanced knowledge base as much learning that is presently not documented can be captured and reused.

## CONCLUSIONS

This paper has set out an approach for the live capture of construction project knowledge, which is intended to reflect both the organisational and human dimensions of knowledge capture and reuse, as well as exploit the benefits of technology. The system comprises of a project knowledge file, and integrated workflow system that can be incorporated with existing project extranets and a project knowledge manager. Further research is required to determine the precise nature and contents of the project knowledge file, the form of the integrated workflow system, and on the development and integration with project extranets. However, the implementation of this system will ensure the currency and relevance of project knowledge and will have significant impact on the construction process.

## REFERENCES

- Anumba C. J., Bloomfield D., Faraj, I. and Jarvis, P. 2000: *Managing and Exploiting Your Knowledge Assets: Knowledge Based Decision Support Techniques for the Construction Industry*. UK: Construction Research Communications Ltd. (ISBN 1 86081 346 1)
- Augenbroe, G., Schwarzmueller, G. and Verheij, H. (2001). "Project web sites with project management extensions: a prototype." In Augenbroe, G. and Prins, M. (eds), *Design Management in the Architectural and Engineering Office*, CIB, Rotterdam, pp. 395-404
- Carrillo, P. M. and Anumba, C. J. (2000), "Knowledge Management for Improved Business Performance," Engineering and Physical Sciences Research Council (EPSRC) Grant Ref: GR/N01330
- Carrillo, P. M, Anumba, C.J. and Kamara, J. M. (2000) "Knowledge management for construction: key IT and contextual issues," in Gudnason, G. (ed.), *Proceedings of the Inter. Conf. on Construction IT, 28-30 June, Reykjavik, Iceland*, Icelandic Building Research Institute, pp. 155-165
- CPN (2002). "Project extranets – the real benefits." Construction Productivity Network (CPN), UK (available at: <http://www.ciria.org.uk/cpnww/0001.htm> )

CSanD, (2001), Creating, Sustaining and Disseminating knowledge for sustainable construction: Tools, Methods and Architecture (C-SanD\_ project website at <http://www.c-sand.org/>)

Davenport, T. (1997), "Secrets of Successful Knowledge Management." *Knowledge Inc.* 2, February.

Digenti, D. (1999), *The collaborative learning guidebook*, Learning Mastery, Somerville, MA.

Dixon, N. M. (2000). *Common Knowledge*, Harvard Business School Press, Boston, MA.

e-COGNOS (2002) Methodology, tools and architectures for electronic, consistent knowledge management across projects and between enterprises in the construction domain (e-COGNOS) project website at <http://www.e-cognos.org/>)

Health and Safety Executive (HSE), (1997), *Construction (Design and Management) Regulations 1994: the health and safety file*, HSE Information Sheet; Construction Sheet No. 44 (available from <http://www.hse.gov.uk/pubns/con44.htm>, accessed 6<sup>th</sup> January 2003).

Kamara, J. M. and Anumba, C. J. (2002), "Collaborative systems and CE implementation in construction" in Tommelein, I. D. (ed), *Proceedings of the 3<sup>rd</sup> International Conference on Concurrent Engineering in Construction, Berkeley, CA, 1-2 July*, pp. 87-98.

Kamara, J. M., Augenbroe, G., Anumba, C. J. and Carrillo, P. M. (2002a) "Knowledge management in the architecture, engineering and construction industry", *Construction Innovation*, Vol. 2, pp. 53-67.

Kamara, J. M., Anumba, C. J. and Carrillo, P. M. (2002b) "A CLEVER Approach to Selecting a Knowledge Management Strategy" *International Journal of Project Management*, 20(3): 205-211.

Kleiner, A. and Roth, G. (1997), "How to Make Experience Your Company's Best Teacher", *Harvard Business Review*, Vol. 75, No. 5, (September-October, 1997), pp. 172-177.

McCarthy, T. J., Kahn, H. J., Elhag, T. M. S., Williams, A. R., Milburn, R. and Patel, M. B. (2000): "Knowledge management in the designer/constructor interface". In Fruchter, R., Peña-Mora, F. and Rodis, W. M. K. editors, *Proceedings of the 8<sup>th</sup> International Conference on Computing in Civil and Building Engineering, 14-16 August*. Reston, VA: American Society of Civil Engineers, 836-843

McConalogue, N. H. (1999), "Knowledge management in the construction industry: a study of major UK contractors", MSc Dissertation, Department of Civil and Building Engineering, Loughborough University, Loughborough, UK.

Orange, G., Burke, A. and Cushman, M. (1999), "An approach to support reflection and organisational learning within the UK construction industry," *Paper presented at BITWorld'99: Cape Town, SA, 30 June-2 July* (<http://is.lse.ac.uk/b-hive>)

Reiner, K. and Fruchter, R. (2000), "Project Memory Capture in Globally Distributed Facility Design," in Fruchter, R., Peña-Mora, F. and Rodis, W. M. K. (eds.), *Proc. 8<sup>th</sup> Inter. Conference on Computing in Civil and Building Engineering*, Stanford University, CA, 14-16 August, ASCE, pp. 820-827.

Scherer, R. J. and Reul, S. (2000), "Retrieval of Project Knowledge from Heterogeneous AEC Documents," in Fruchter, R., Peña-Mora, F. and Rodis, W. M. K. (eds.), *Proc. 8<sup>th</sup> Inter. Conf. on Computing in Civil and Building Engineering*, Stanford University, CA, 14-16 August, ASCE, pp. 812-819.

Stewart, T. A. (1997), *Intellectual Capital: The New Wealth of Organisations*, New York, D'bleday.

Tiwana, A (2000) *The Knowledge Management Toolkit*. Prentice Hall, New Jersey.