# Knowledge and Experience Sharing in Projects-based Building Maintenance Community of Practice

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## ABSTRACT

Knowledge and experience are regarded as the most important assets for sustainable success in today's knowledge-based economy, and knowledge has become the major competitive tool for many businesses. It is argued that the proper sharing, capture and reuse of knowledge minimizes the risk of reinventing the wheel and repeating mistakes, as well as offering many other benefits. Owing to the unique nature of building maintenance projects, building professionals need

sufficient technical, product and project-organizing knowledge and experience to facilitate their decision making. Apart from gaining this knowledge and experience by learning on the job, learning from others is an important alternative. However, insufficiencies have been found in the current practice on this aspect, thus the aim of this study is to examine whether knowledge and experience in building maintenance projects could be reused in a more effective and efficient way by forming a community of practice across organizations and whether a proposed web-based experience management system would be a feasible solution in the sharing, capture and reuse of knowledge and experience in building maintenance. A questionnaire survey and interviews were conducted to study the opinions of building professionals on various issues related to the sharing, capture and reuse of knowledge and experience in building maintenance projects, as well as the requirements of a proposed web-based system. Based on the findings, a proposed system was developed and evaluated. The evaluation aimed to test the validity of the system in a real-life situation with professionals who had day-to-day experience in maintaining building stocks.

**Keyword:** *Buildings, residential; Buildings, high-rise; Maintenance; Knowledge Management; Projects; Experience Management; Building Surveyors; Facilities Managers; Web-based System; Community of Practice*

## Introduction

Building maintenance is “the keeping, holding, sustaining or preserving of a building and its services at an acceptable standard to enable its function” (Brett, 1997). In real-life situations, certain knowledge and experience get lost when a project is finished. Lessons learned in previous

projects cannot be reused, and the consequence is “actions and decisions that caused problems and errors may be repeated” (Disterer, 2002). Professionals waste their time and effort on reworking tasks and procedures that have already been solved by others in the past. One of the common problems of this issue in Hong Kong is water seepage through windows, which is a major concern in any building projects.

In the current situation, it is difficult for building professionals outside a project team to understand the knowledge and decision rationales involved by simply referring to materials kept upon the completion of the project. Kamara *et al*. (2002) argue that the “capture, transfer and reuse of the project knowledge are critical”, as knowledge is being treated as one of the most important resources of an organization (Nonaka & Takeuchi, 1995) and may be “the only meaningful resource” (Drucker, 1993). In addition, peculiar features of building maintenance work are that there exist fragmented structures and the strategy of project-silo, which seem not compatible with the effective management of knowledge. Davenport (1996) and Ahmed *et al.* (2002) point out that effective knowledge management pays off in fewer mistakes, less redundancy, quicker problem solving, better decision making, increased staff independence, enhanced customer satisfaction, and improved products and services that will stay ahead of competitors. In view of these points, it is worth studying ways of capturing, transferring and retrieving knowledge and experience in building maintenance projects through an online community of practice, in order to facilitate the reuse of this knowledge and experience in other similar ones. The aim of this research is to examine whether knowledge and experience in building maintenance could be reused in a more effective and efficient way, and to determine whether a proposed web-based prototype system would be a feasible solution to the problem.

The significance of this research lies in the strength of filling these research gaps and providing a flexible knowledge management solution that does not attempt to formalize all the knowledge required in building maintenance projects but rather creates an informal environment that encourages professionals to share knowledge, collaborate and learn from others' experiences.

## Knowledge and experience management in building maintenance projects

Like new construction work, building maintenance projects involve multiple stakeholders who individually possess diverse sets of knowledge and skills. They act as a moveable feast that moves from one project to another and continuously accumulates experience. In addition, a maintenance project involves plenty of information, knowledge and experience that is related to the actual situation and condition and requires decision making by different parties according to the context.

Experience is defined in Webster's dictionary as "knowledge or practical wisdom gained from what one has observed, encountered, or undergone" (Anon., 2001). Bergmann (2002) defines experience as "valuable, stored, specific knowledge that was acquired by an agent in a previous problem-solving situation" and is useful for future re-use by the agent. Both definitions imply that experience can only be gained by humans. Such experience may be stored tacitly (i.e., in human brains) or explicitly (i.e., documented). Another important criterion is that experience is always gained in a *context*, that is, it is context-dependent. Since experience is defined as specific knowledge, it is necessary to consider management of this specific knowledge as part of knowledge management.

Examples of building maintenance knowledge and experience include project location and proximity, response time, nature of repair work, performance of different materials and techniques over time, contractors' and suppliers' details, cost data, contractors' performance and latest maintenance technologies and materials. In addition, health and safety issues can be critical for maintenance work in occupied premises, e.g. removal of asbestos-cement products, repair to existing structure, etc.

Owing to the high percentage of building maintenance work in relation to total work in the construction industry, many researchers have examined various aspects of building maintenance, including the use of IT, but little research work has been carried out that touches on knowledge management in building maintenance projects. Ahmed *et al.* (2002) find that the growth and development of the Internet, which enables access to information at any time, by anyone and from anywhere, has been influential in the promotion of knowledge sharing opportunities. Furthermore, web-based technologies improve inter-firm communication and the reduction of time delay in information flows (Mohamed, 2003). Different researchers and scholars have expressed similar points of view as follows: "when utilized appropriately, information and computer technology can serve as powerful enablers of knowledge management" (Tannenbaum & Alliger, 2000). Sallis and Jones (2002) state that the increasing use of information technology enhances the sharing of explicit knowledge, and that virtual networking is a proper channel for sharing tacit knowledge. However, technology serves as nothing more than an enabler in knowledge management. This is because "without humans to create and use the knowledge, the knowledge itself remains worthless information" (Koulopoulos & Frappaolo, 1999). Nevertheless, they added that technology helps a lot in the transfer of explicit knowledge, and

can also assist in “brokering the owners of tacit knowledge and facilitating the creation of people-based networks” (Koulopoulos & Frappaolo, 1999).

Building maintenance work demands effective management in order to avoid unnecessary time, cost, energy, paperwork and rework. A maintenance project involves the client, who is usually the building owner or a property/facility management company; a facilities management team, in-house or outsourced by the client; consultants (e.g. building surveyor, structural engineer), either in-house or independent; contractors, subcontractors and suppliers. Maintenance work can be subdivided into different categories as specified in BS 3811 (BSI, 1993): automatic, condition-based, controlled, corrective, deferred, emergency, function-degrading, function-permitting, function-preventing, opportunistic, planned/unplanned, preventive, scheduled/unscheduled maintenance.

The first body of building maintenance knowledge required is on the classification of repair types. This involves the partitioning of all the possible maintenance problems under the high-level repair type, which require the project team’s attention or problem-solving. A general building maintenance classification is defined and split into three headings:

1. Building – problems associated with the actual structure, e.g. floor, roof, ceiling, etc.
2. Equipment – problems associated with pieces of equipment, e.g. furniture, sound system, etc.
3. Services – external services called in to maintain, e.g. pest control, waste disposal, etc.

Professionals such as building surveyors, facilities managers and structural engineers rely on knowledge as their primary product. These professionals are similar to management consultants

and accountants in two ways: (1) knowledge and skills are their chief products, and (2) their success lies in the ability to create, capture and share knowledge. Building surveyors and the like, faced with unique building maintenance problems, require highly customized technical solutions that emerge from the initiative of individual consultants who seek information during the performance of their jobs. As their superiors are only loosely involved in its coordination, knowledge-sharing efforts are informal and people-oriented, attempting to connect less experienced consultants to those with considerable experience and expertise (Sarvary, 1999). Of course, when faced with common building maintenance problems, standardized solutions suffice. This places a greater emphasis on the formal deployment of information technology to collect and distribute knowledge from the central organization. According to Sarvary (1999), large firms with large customer bases are most likely to achieve a sustainable advantage in the competitive environment using technology. Hansen *et al.* (1999) termed these two knowledge management strategies personalization and codification.

The personalization strategy is driven by providing highly customized client solutions that are rich in tacit knowledge. Firms hire employees, train them by assigning them to work with more experienced consultants who serve as mentors, and reward them for sharing knowledge with others. They share information through conversations, brainstorming sessions, and communication via telephone and email – with little or no emphasis on technology or document management. In addition, they also allow their protégés to observe how they tackle problems and make decisions. The drawback of this approach is that person-to-person knowledge sharing efforts are often time-consuming and expensive.

The codification strategy relies heavily on information technology, allowing companies to reuse information at a low cost, provided it does not have to be substantially modified for each use (Hansen *et al.*, 1999). This strategy reduces work and communication costs and allows a company to take on more projects (Hansen *et al.*, 1999). In this instance, less specialized knowledge is required. Junior employees learn to solve problems using the information provided by the company's information system. Rewards are designed to promote the use of information systems and build the firm's knowledge database.

Taylor *et al.* (2001) surveyed professionals in a large, international accounting firm and found that the firm's attitude towards the importance of information is clearly related to the job satisfaction of its staff. An organization with a high level of information consciousness will have more satisfied employees and in turn be more effective.

Since knowledge in building maintenance projects is accumulated through years of experience, that knowledge will disappear if an employee leaves a firm or retires, or upon the completion of a project. The competitive edge a company possessed may be seriously undermined. In addition, knowledge is scattered among all the project stakeholders and embedded in documents, routines and procedures which may not be easily uncovered. The availability of expertise may never be realized if it goes "un-marketed" by the holder or unsolicited by prospective users. Further, the expertise could be imperfect if it is based on the reputation of individuals who may lack important skills or miss the latest developments that decrease the "shelf-life" of the expertise. Having realized some of the detriments of not leveraging knowledge and expertise within a firm, Kasvi *et al.* (2003) suggest that systematic knowledge management is needed if an organization

wants to evolve into a learning organization and apply the solutions and lessons from one project to another. Lundin and Midler (1998) shed similar light, as a project in itself cannot and has not been created to memorize and store what has been learnt. Consulting assignments can be enhanced with the integration of lessons learned from previous ones. Lessons learned in previous assignments, stored in an organization's memory system, can be good learning materials for those who were not involved in that project but have valuable lessons to learn from. In addition, the time restrictions of projects make the reuse of knowledge necessary. Without the reuse of existing knowledge, organizations have to create their own solutions to every problem they face. However, these problems may have been dealt with previously in other assignments. With the reuse of knowledge, organizations can operate more efficiently, and thus the time requirement can be fulfilled more easily. Prusak (1997) stressed that knowledge management is not just to save time and money, but to avoid reinventing the wheel, which results from the failure to capture and transfer knowledge. Further, knowledge management helps to contribute to improvement in the organizational business processes, which can otherwise become obsolete. Though knowledge is the prime focus of knowledge management, learning can be seen as the other side of the same coin, i.e. they are very closely linked to each other. Antonacopoulou (1999) expressed concisely the relationship between the two: "learning informs knowledge and … existing and new knowledge fuels learning".

## Research methodology

In order to design and implement a sustainable community of practice, a good design and implementation methodology is essential. The methodology that has been used in this study is shown in Table 1.

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The first step in designing and implementing a knowledge management solution is recognizing the need of such a system and identifying the major factors that influence the need to create a knowledge management system. This will provide a general appreciation of the community's strengths and weaknesses in managing its knowledge. The second step is to develop a clear definition of the existing problems, based on the results of the previous step. The third step in the design and implementation process is the identification of the requirements. The purpose of this step is to identify the community's requirements and the specifications that the system needs to meet. The next step is to design a knowledge management system. This can be an assessment and adaptation of an existing system, designing a totally new system or buying a suitable new system. The fifth step is the testing and optimizing phase, the purpose of which is to improve and adapt the system before it is implemented in the community of practice. The purpose of the sixth step is to implement the knowledge management system systematically, using project planning and other methodologies appropriate to the system with a view to integrating this system with the business activities. The last step is post-implementation review. The purpose of this step is to evaluate the system development process so that deficiencies can be remedied and avoided in the future. This methodology is not a linear one: there needs to be current feedback. Only steps 1 – 5 are covered in this paper.

In this research, a questionnaire survey was used to investigate the opinions of professional building surveyors regarding the capture and reuse of knowledge and experience in building

maintenance projects and to study the requirements of a proposed web-based prototype system. Fifty questionnaires were sent to professional building surveyors working in the Architectural Services Department and the Housing Department whose responsibilities are in maintaining government buildings. Out of the 50 questionnaires sent, 31 completed questionnaires were returned, representing a response rate of 62%. In-depth interviews with professional building surveyors were carried out after the survey. The purpose was to capture the knowledge and experience used by building surveyors in building maintenance projects, as well as to use that knowledge to develop the prototype system. Questions focused on the specific knowledge and experience required in these cases. Based on the survey and interviews, the requirements of the system were obtained and used as a guide for development of the web-based prototype system. The prototype system was designed with several objectives in mind: (1) to provide a user-friendly approach in the process of retrieving knowledge and experience; (2) to provide a simplified approach in the process of submitting and contributing knowledge and experience; and (3) to allow communication between different users of the system and enhance the exchange and sharing of knowledge and experience related to building maintenance projects.

It is important to note that the system was not designed to provide any generalized rules related to building maintenance, because the survey found that knowledge in building maintenance projects is context-specific and cannot be generalized. Instead, the system allows users to share and retrieve the knowledge and experience of other practitioners in building maintenance, in order to facilitate their own decision-making process. That is, the system utilizes both the codification and personalization strategies to establish the system, and the latter strategy supplements the former one.

## Data analysis

This section presents and analyzes the results of the questionnaire survey, which provides a summary of the opinions of professional building surveyors regarding the capture and reuse of knowledge and experience in building maintenance projects and the requirements of the proposed web-based prototype knowledge management system for the community of practice.

All the returned questionnaires were completed by professional building surveyors who had worked in the area of building maintenance. These 31 professional building surveyors had been involved in building maintenance projects for different lengths of time. 11 of them had been involved in the area for more than 15 years, the same number had been involved for 10 to 15 years, and the remaining 9 had been involved for 5 to 10 years.

### Capture and reuse of knowledge and experience

Understanding the nature of knowledge and experience in building maintenance projects, as well as the opinions of professional building surveyors regarding the capture and reuse of knowledge and experience, could enhance the development of the proposed web-based prototype knowledge management system for the community of practice.

Nature of knowledge and experience in building maintenance projects

Table 2 summarizes the results of the survey regarding the nature of knowledge and experience in building maintenance projects. From the mean scores of the four statements in Table 2, the results lay between “strongly agree” and “agree”. We can interpret this as meaning that

respondents view building maintenance as a knowledge-intensive discipline where experience gained from previous projects can enhance future practice.

Most of the respondents agreed that the knowledge gained from experience can enhance similar work in building maintenance projects. The personnel involved in a project can be referred to as 'knowledge carriers' whose knowledge learnt from one project can be applied to others. By the same token, knowledge will be lost if the person retires, leaves the company or completes the project. This is one of the key factors that motivates most companies to capture or codify their employees' knowledge for future use/re-use: it is costly to train up a new staff member. However, it must be noted that knowledge without context is futile. Hence, context plays an important role in producing knowledge. It is one of the key aspects that is considered when designing the prototype building maintenance knowledge management system. Schilling *et al.* (2003) highlight the importance of striking a balance between providing employees with specialization and diverse experience and avoiding excessive experience specialization amongst employees. Diverse experience can improve the absorptive capacity of employees (Cohen & Levinthal, 1990), which is a function of the individual's pre-existing, relevant knowledge in the particular task domain. A building maintenance community of practice can enable knowledge sharing and foster collaboration.

It is interesting to note that practitioners with longer working experience tend to agree more that their work requires lots of knowledge, both explicit and tacit. A very small percentage of all the respondents disagreed that building maintenance projects requires a lot of knowledge, possibly due to the fact that they are so specialized in a particular area over a long period of time that they

do not see any high level knowledge input in their daily work. In a project environment like that of building maintenance, appropriate expertise deployment means that members of the project have expertise that matches the project requirements. However, as mentioned previously, management needs to strike a balance between specialization and the diverse experience of employees.

Though some building maintenance knowledge has been codified into explicit knowledge such as codes of practice, standards or guidelines, practitioners find that they also need to rely on their own personal experience, accumulated through years of practice. This is something that cannot be expressed: it is an embodied skill or something that can only be learnt by socialization, accrued by experience or embedded. It is almost impossible to reproduce in a document or database. Examples include judgment, 'rules of thumb', etc., which are referred to as tacit knowledge by Nonaka and Takeuchi (1995). A similar point of view is shared by Wetherill *et al.* (2002), who state that knowledge in the field usually resides in the minds of the individuals working within the domain.

The majority of the respondents agree that the knowledge required in building maintenance projects is not completely covered in codes of practice and other well-known standards and guidelines, and that some knowledge is built up from personal experience. This shows that building surveyors practicing in building maintenance cannot simply obtain all their required knowledge by referring to published materials. Research by Fong (2003) reveals that a practitioner's social network can be an important vehicle for information and knowledge exchange, with people within the network generating knowledge through their experience or issues that they have come across previously. One thing that building respondents have found in

a project-based industry like construction is that knowledge gains are useful for both future and concurrent projects.

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Willingness to share knowledge and experience in building maintenance projects

Table 3 summarizes the results of the survey regarding the willingness of professional building surveyors to share knowledge and experience in building maintenance projects. The majority of the respondents agreed that sharing building maintenance knowledge and experience is mutually beneficial, as the knowledge required for each project is so diverse that no one will have all the knowledge required for the job. In fact, this is another objective of the prototype knowledge management system: to allow people to share and tap into the knowledge of others, as there is no automatic transfer mechanism for projects to share experiences with other projects routinely and naturally. In addition, from the results, people see knowledge gained as a personal asset which can enhance their employability in the job market or help them attain promotion within their companies. Unfortunately, when people see knowledge as having a price tag, this also creates a knowledge-hoarding culture in which they see 'knowledge as power', or one perceives that sharing one's knowledge with one's colleagues will undermine one's position within the company, or worse still, the company may get rid of the one who shared. Generally, one of the key missions for most companies is to cultivate a knowledge-sharing culture in order for knowledge management to be successful. Another major barrier for companies to cross is trying to capture employees' knowledge into their database or repository. Hansen *et al.* (1999) showed that effective firms excel predominately by focusing on using either the personalization or codification knowledge-sharing mechanism, and using the other in a supporting role. They noted

that companies do not use both approaches to an equal degree.

Regarding the statement whether building surveyors in practice like to share their knowledge and experience in building maintenance projects with others, the mean score falls to between 'agree' and 'slightly agree'. This shows that respondents generally feel that professionals are reluctant to share their professional know-how with others. This result also contradicts the other statement. On one hand, people know that sharing knowledge and experience can be mutually beneficial, as no one has all the knowledge. On the other hand, they see knowledge as a personal asset and will guard it carefully. This uncertainty may be a possible barrier for sharing knowledge and experience in building maintenance projects because, as Ives *et al.* (2000) stated, knowledge sharing is a human behavior and cannot be fostered without genuine trust. This is the main reason why there is an increasing number of publications (e.g. Cohen & Prusak, 2001; Anand *et al.*, 2002) emphasizing that social capital should be used to make knowledge management work.

In general, professional building surveyors with fewer years of experience were more likely than those with more experience to agree with the proposition that building surveyors in practice like to share their knowledge and experience. This indicates that professionals with more accumulated experience think that people are more reluctant to share their knowledge with others. This can be explained by the fact that people see knowledge as an important personal asset for advancing within their organizations, as well as an asset to offer to their clients. This situation explains why they become 'knowledge silos' within their organizations: unless they are willing to share their knowledge and experience, their companies are taking the risk of losing that knowledge when they leave the firm or upon their retirement. In fact, there is a bigger chance

that colleagues will repeat the same mistakes if the knowledge learned from previous projects is not shared.

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Current practice of knowledge and experience management

Table 4 summarizes the results of the survey regarding current practices in knowledge and experience management in building maintenance projects. Generally, responses ranged between 'strongly agree' and 'agree' regarding whether the management of knowledge and experience in building maintenance would be beneficial to the profession. Doing so can enhance one's experience through learning from others' experience or best practice. From a firm's perspective, it enhances its knowledge resources, builds up its capabilities and establishes its competitive advantage. In addition, it broadens the professional horizon of practitioners to know that there may be better ways of doing things. One can imagine that professionals would like to improve on their professional service rather than keep on "reinventing the wheel" or repeating the same mistakes.

Regarding reassigning personnel to other similar projects, the mean score lies between 'agree' and 'slightly agree', implying that it may not be as common as it should be in project-based organizations. Currently, two principal criteria appear to be used in selecting members for a project. The first criterion relates to past and similar experience. For example, if a building surveyor has previous experience in steel structures, he or she would be a logical choice for appointment to a project where this is a key requirement. This is in concurrence with findings by

Kamara *et al.* (2002) on the current practice of knowledge management in the architecture, engineering and construction industries: the survey revealed that most of the respondents agreed that reassignment of a practitioner with relevant knowledge and experience to other similar projects is the most common way to reuse knowledge and experience. However, there is a possibility that candidates suitable for certain projects may be irrevocably engaged elsewhere and unavailable for immediate involvement in any new project. With such scenarios in mind, some companies prefer not to allow too much specialization, since this can limit staffing flexibility. Moreover, should specialists leave, they take away a wealth of knowledge and experience that may be lost to another, rival consultancy. Some companies prefer to establish wide-ranging diversity in staff members so that certain employees have similar, mutually interchangeable capabilities and skills. The second criterion used to select project team members was that of availability. This can be called a 'pool system of managing staff resources' - whoever is available will be allocated to the project.

The management of knowledge and experience in building maintenance is regarded as of neutral importance in the profession/industry: there were almost equal percentages of respondents who supported or did not support this statement. In Hong Kong, due to the enormous number of facilities that are constructed, the effort of maintaining and keeping them in good condition is of paramount importance. Since the outbreak of Severe Acute Respiratory Syndrome (SARS)**,** maintaining healthy buildings has become even more important. Currently there are a number of education institutions in Hong Kong offering facilities or property management degrees at bachelor's or master's degree levels. Perhaps professional societies and universities, in collaboration with practitioners, can act as a driving force in promoting the sharing of knowledge

and experience in proper building maintenance.

Respondents slightly disagree with the statement that there are enough ways in the profession to enhance the sharing of knowledge and experience in building maintenance projects. This may be due to the fact that there are not sufficient channels for professionals to share their knowledge in this specific field. One may argue that the professional society for surveyors could be a channel for disseminating and sharing knowledge. However, building maintenance is only part of the scope of their professional service. In addition, it is not easy to gather all the like-minded people together to share their practices. Secondly, the competitive nature of the construction industry may dissuade people from sharing with professionals from rival firms.

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**Requirements of the proposed web-based prototype system**

Since professional building surveyors practicing in building maintenance projects are the targeted end-users of the proposed web-based prototype knowledge management system, it is important to understand their opinions on the requirements of the proposed system. The study of the requirements is based on two main aspects, namely the general requirements of the system and the provision of certain functions in the system.

General requirements of the proposed web-based prototype system

General requirements of the proposed web-based prototype knowledge management system include the major objective of the system, the importance of classification of knowledge and

experience in the system, and the capacity of knowledge in the system. The survey results regarding the opinions of the respondents on these general requirements of the proposed system are summarized in Table 5.

The results show that most of the respondents agreed that the proposed system should be designed to facilitate the retrieval of knowledge, with 80.6% of all respondents expressing their opinions as “strongly agree” and “agree”. The majority of the respondents agreed that the greater the number of cases the proposed system contains, the better the system would be. Again, most of the respondents agreed that proper classification of knowledge and experience of building maintenance are important in the proposed system. Respondents had different opinions on the proposition that knowledge in building maintenance projects is context-specific, where 67.7% of all respondents expressed at least slight agreement with this proposition.

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Provision of specific functions in the proposed web-based prototype system

A summary of the survey results regarding whether it is necessary to provide specific functions in the proposed system is given in Table 6. More than 87.1% of all respondents “strongly agreed” or “agreed” that the proposed system should be equipped with a search function for finding a specific kind of knowledge and experience in building maintenance. In addition, 80.6% of all respondents “strongly agreed” and “agreed” that the proposed system should be provided with functions (e.g. a discussion forum) to enhance sharing of knowledge and communication. In addition, 80.6% of all respondents “strongly agreed” and “agreed” that a function for comparing

similar cases is important in the proposed system. It was found that the results of the survey regarding the provision of some specific functions in the proposed system were similar to suggestions by different researchers and scholars in the literature, such as Haas *et al.* (2003), Yeung & Holden (2000) and Skyrme (2000).

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## Web-based prototype building maintenance system

The web-based prototype knowledge management system is a website built and located on the Internet and can be hosted by providers such as Yahoo or Google. The website does not require the targeted users to have any additional software program knowledge other than that of how to use the web browser. The proposed system combines both knowledge-sharing mechanisms for sharing knowledge across projects. The personalization mechanism, such as the email function to contact the case contributor and the discussion forum, facilitates the sharing of knowledge that is closely tied to the person who developed it and shared directly through person-to-person contact. The codification mechanism allows knowledge to be codified and stored in the web-based system, where it can be accessed and used easily by practitioners. This proposed system is different from other knowledge management systems in that it allows both tacit and explicit knowledge to be shared and exchanged. The codification side provides professionals the opportunity to use a repository for sharing building maintenance knowledge and experience, and the personalization aspect allows the seeking of assistance from the case authors or other forum participants by making use of a shared interpretive schema to guide their understanding and interpretation of it.

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To reuse knowledge and experience in building maintenance projects, it is necessary to allow users to retrieve knowledge and experience that is relevant to their own decision-making process. The performance of the system in this aspect will affect its usefulness greatly. On the index page, users are informed that there are two different approaches provided in the system to facilitate the retrieval of knowledge and experience. These are *"Browse by Search"* and *"Browse by Topic"*.

*"Browse by Search"* is a function which allows users to retrieve relevant knowledge by carrying out a keyword search. Users can enter the keywords in the blank spaces provided and select the targeted field where these keywords appear from the list provided. Several fields are available for users to choose from, including title, executive summary, main text, etc. *"Browse by Topic"* is another function facilitating the retrieval of knowledge and experience. A list of topics is provided and users can choose the one that matches the area containing their targeted knowledge and experience. Users can view cases under a particular topic provided by clicking the topic, which is actually the hyperlink to that specific page.

In each building maintenance case, *headings* and *sub-headings* are provided with the aim of assisting users in understanding what knowledge and experience are being shared, and enabling them to locate that knowledge efficiently. An *executive summary* is provided to summarize the major knowledge and experience in the case. Information regarding the building maintenance project and the building defects found and remedied is provided in *background information*. The

major part of the building maintenance case is the reason for the defects and the remedial methods employed. Details of the causes of the defects are presented under *details of causes*, and the remedial methods are presented in *our method for repairing*. The *cases button* allows the user to view other similar cases in the system so that they can easily compare different cases.

The *name* of the building professional who submitted this particular case is provided at the bottom of the page. The user can click on the name and a pop-up window will appear for the user to send an email to that contributor. This feature enhances direct sharing between the knowledge contributor and the knowledge user. Another feature of the system to enhance communication between different users is the *discussion forum*. The purpose of the discussion forum is to allow users to comment and exchange ideas on the knowledge and experience being provided. This allows knowledge sharing in the community other than via the case repository. Users can access the forum by clicking a button located at the bottom of the page in each building maintenance case. The forum contains a list of the topics submitted by other users. The user can click on the topic and view the materials being discussed. Apart from viewing previous discussions, the user can compose and post a new discussion topic to the forum. Once confirmed, the new topic will appear on the list of topics in the forum.

**Usefulness of the web-based prototype building maintenance system**

To test the validity of the web-based prototype knowledge management system in a real-life situation, the system was evaluated by building professionals practicing building maintenance. As such systems should be user-oriented (Skyrme, 2000), Ives *et al.* (2000) suggested that users should be consulted in the functional and interface design of the knowledge sharing system,

because it is designed for the specific needs of a particular user group. Understanding the requirements of these users can assist the process of development.

The prototype system is, therefore, a one-stop point access for practitioners to building maintenance information resources, services, tools and facilities such as discussion forums, expertise-locator, document sharing, and electronic white boarding.

Practitioners found that the use of the proposed information portal in the provision of access to digital information services in building maintenance projects had several advantages. It could provide increased functionalities and improved access to information resources and services to practitioners within and across organisations. The building maintenance information portal could also enable practitioners/researchers, through a single user interface:

- To gather/bring content and services from a variety of sources and aggregate them into a single point that can be accessed by researchers and practitioners.
- To provide practitioners/researchers with access to a variety of information resources and services to support their work on their desktops or working remotely, through a single web-based interface.
- To support a single log-on to obtain authentication and authorisation to all information resources and applications.
- To allow practitioners to personalise and customise the presentation of information and services they would like to access on the portal.
- To promote collaboration and sharing of data, information and knowledge among researchers/practitioners.

- To improve productivity through quicker access to proven information resources and knowledge generated within and outside the organisations.

In the above context, the success of the portal could then be measured by asking whether it meets the above goals and objectives. It was found that practitioners were generally satisfied with the web-based prototype system, except for the search function of the system, which still has room for improvement because practitioners agreed that an advanced search is necessary for the system to further limit the results of a search. As explained by Kelleher and Levene (2001), an advanced search could help users achieve very good matches of query to result. Some characteristics of this advanced search include the ability to cope with misspelling of words, and allowing users to query content by using everyday sentences, which are then converted to a structured form automatically by the system.

**Areas for further improvement**

The following have been identified by practitioners during the evaluation stage as major features that should be incorporated into the building maintenance information portal:

- *Personalisation for end-users*: The portal should allow information end-users to personalise its appearance, content and application interface to suit their individual needs. This feature ensures that information end-users are able to reduce the state of information overload.
- *Tracking of individuals' usage, interests and use behaviour*: The portal should track the individual usage, interests, and behaviour of users to enable the users to personalise the

portal, and the portal to present a personalised view of the information resources to the user.

- *Provision of access to multiple heterogeneous data resources*: The portal should be able to provide users with access to information from multiple heterogeneous data stores.
- *Provision of facilities for locating information and people*: The portal must make it easy for users to locate people and the building maintenance information they need.
- *User authentication:* The portal should provide user authentication and login facilities to facilitate the provision of content that is relevant and current to the users' needs.
- *Taxonomy*: The organisation of portal resources should be based on a well-defined categorisation system of content or subject.

Arising from the above findings, the following should be taken into account:

- The proposed building maintenance information/knowledge portal should have potential applications to organisations responsible for new-build, alteration or maintenance of high-rise residential buildings in the region.
- The variety and number of digital information resources and services being provided in the websites for building maintenance information were very limited.
- Construction-related organisations in the region were using ad hoc system development approaches to develop their websites.
- There was a need to deploy advanced websites or information portals in order to improve access to web-based, value-added information services and resources to researchers/practitioners.

It is therefore recommended that building maintenance personnel in the region should:

- Take advantage of the Internet and Web-based technologies and start utilising the advanced website or information portal to facilitate the provision of access to digital information resources and services to researchers/practitioners. Use of the advanced website and portal would also enable organisations to provide researchers/practitioners with access to as much locally produced proven information content as possible, including research reports, articles, technical guides, models, data sets and other relevant materials produced by organisations, researchers or practitioners.
- Adopt the use of formal system development methodologies in the development of the advanced website/information portal. Use of formal methodologies would ensure that building maintenance organisations avoid the various problems associated with the use of ad hoc approaches in website development. This will also ensure that the website/portal that is developed is sustainable and fit into organisations' overall information strategy. In addition, the industry-wide portal can leverage on a larger pool of expertises to solve emergent problems related to building maintenance projects that may recur from time to time.

## Conclusions

This research has identified the nature of knowledge and experience in building maintenance, as well as the opinions of building professionals on the capture and reuse of knowledge and experience in building maintenance projects. The survey results reveal that building maintenance is a complex process requiring a lot of knowledge. Knowledge required cannot simply be obtained by referring to published materials, as some knowledge is built up by personal

experience and becomes the personal asset of practitioners in the field. Whether practitioners can learn from the knowledge and experience of others will highly depend on the willingness of the practitioner who has acquired the knowledge and experience to share them with others. However, this study revealed varying opinions on whether building surveyors in practice like to share their knowledge and experience with others. This uncertainty may be a barrier to sharing knowledge and experience in building maintenance projects, as knowledge sharing is a human behavior and cannot be fostered without genuine trust. It would be difficult to build up the necessary trust if building surveyors do not have a clear concept of whether others are willing to share their expertise.

Based on the result of the survey and interviews, a web-based prototype knowledge management system was proposed and designed with the aim of facilitating the reuse of knowledge and experience in a building maintenance community of practice. A clear and well-defined structure with proper classification of knowledge and experience in building maintenance is necessary to help in achieving the aim. In order to test the validity of the system in a real-life situation, the system was evaluated by professionals practicing building maintenance through the completion of an evaluation questionnaire. The evaluation found that the system should be equipped with an advanced search function, which could assist in further limiting the results of a search. Further, the results showed that professional building surveyors prefer to browse by topic in the system in order to retrieve a relevant case. It was also suggested that an index be provided for all cases under a specific topic in the system.

The system was found to perform well, as sufficient guidelines were provided, and knowledge

and experience were illustrated by suitable means such as photographs. In addition, the simple approach to the process of submitting and contributing knowledge and experience was found to be a success. Nevertheless, it was affirmed that the system should not be designed to provide any general rules in building maintenance, as knowledge in building maintenance projects is context-specific. It is more important for the system to illustrate the rationales behind decisions, and allow users to retrieve the knowledge and experience of other practitioners in order to facilitate their own decision-making process. Other than codifying the building maintenance knowledge and experience, the proposed system should be equipped with personalization functions, such as a discussion forum to provide an area for different users to exchange their experience and knowledge and email contact to facilitate communication between knowledge contributor and knowledge user.

## Recommendations

This study can act as a cornerstone in research into the capture and reuse of knowledge and experience in building maintenance projects. Further research by academics and professionals is necessary to make the application of the research results in real-life situations successful and beneficial.

Building maintenance involves the participation of many professionals, including building services engineers, architects, facilities managers, etc. It would be beneficial to all professions if the system could consider the capture and reuse of knowledge and experience from different professions in building maintenance projects. In addition, the knowledge management system could be used by other professionals during the design stage to prevent the repeating of mistakes

that have caused problems in completed buildings due to inappropriate design.

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**Table 1: Design and implementation of an online building maintenance community of practice**

| Steps | Features | Relationship with current study |
|---|---|---|
| Step 1 | Recognition of need | Through literature review and real life situation |
| Step 2 | Problem definition | Through defining study objectives |
| Step 3 | Identify the requirements | Through questionnaire survey and interviews |
| Step 4 | Design online community of practice | Through information collected from survey and interviews for designing prototype web-based knowledge management system |
| Step 5 | Test and optimize online community of practice | Testing by professional building surveyors |
| Step 6 | Implement online community of practice | Pending |
| Step 7 | Post-implementation review | Pending |

**Table 2: Nature of knowledge in building maintenance projects**

| Item | Mean | Standard Deviation |
|---|---|---|
| Knowledge gained from experience could enhance similar works in building maintenance | 1.61 | 0.99 |
| Building maintenance requires a lot of knowledge | 1.65 | 0.84 |
| Some knowledge of building maintenance is built up by personal experience | 1.71 | 1.13 |
| Knowledge required in building maintenance is not covered completely in codes of practice and other well-known standards and guidelines | 1.97 | 1.05 |
| Key: on a 6-point scale: 1 = Strongly Agree; 6 = Strongly Disagree | | |

**Table 3: Willingness to share knowledge in building maintenance projects**

| Item | Mean | Standard Deviation |
|---|---|---|
| Sharing of knowledge and experience would be beneficial to you and others | 1.55 | 0.96 |
| Knowledge gained from experience is a kind of personal asset | 1.68 | 1.30 |
| Building surveyors in practice like to share their knowledge and experience in building maintenance with others | 2.45 | 1.15 |
| Key: on a 6-point scale: 1 = Strongly Agree; 6 = Strongly Disagree | | |

**Table 4: Current practice of knowledge and experience management in building maintenance projects**

| Item | Mean | Standard Deviation |
|---|---|---|
| Management of knowledge and experience in building maintenance would be beneficial to the profession | 1.48 | 0.81 |
| The most common way in the industry to reuse the knowledge and experience of a participant in building maintenance is to reassign that person to other similar projects | 2.74 | 0.77 |
| At present, management of knowledge and experience in building maintenance is regarded as an important aspect in the profession/industry | 3.26 | 1.53 |
| There are enough ways in the profession to enhance the sharing of knowledge and experience of building maintenance | 4.00 | 1.06 |
| Key: on a 6-point scale: 1 = Strongly Agree; 6 = Strongly Disagree | | |

**Table 5: General requirements of the proposed system**

| Item | Mean | Standard Deviation |
|---|---|---|
| The proposed system should be designed to facilitate the retrieval of knowledge | 1.81 | 0.95 |
| The greater the number of cases the proposed system contains, the better the system will be | 1.90 | 0.98 |
| The proper classification of knowledge and experience of building maintenance is important in the proposed system | 2.03 | 1.05 |
| Knowledge in building maintenance is context-specific, i.e. related to the circumstance, and cannot be generalized | 2.87 | 1.41 |
| Key: on a 6-point scale: 1 = Strongly Agree; 6 = Strongly Disagree | | |

**Table 6: Provision of specific functions in the proposed system**

| Item | Mean | Standard Deviation |
|---|---|---|
| The proposed system should be equipped with a search function for finding a specific kind of knowledge and experience in building maintenance | 1.84 | 1.13 |
| The proposed system should be provided with functions (e.g. a discussion forum) to enhance sharing of knowledge and communication | 1.97 | 1.02 |
| A function for comparing similar cases is important in the proposed system | 2.03 | 0.98 |
| Key: on a 6-point scale: 1 = Strongly Agree; 6 = Strongly Disagree | | |

**Fig. 1**: **The main page of the web-based prototype system**