

# **Project Performance Framework: The Role of Knowledge Management and Information Technology Infrastructure**

Amran Md Rasli and Wan Maseri Wan Mohd\*

## **Abstract**

In the new construction era, construction projects are influenced by many unpredictable factors. In an unpredictable and uncertain environment, one of the major sources of sustaining competitive advantage is utilizing knowledge management and information technology to boost project performance. This article proposes to empirically investigate whether Knowledge Management (KM) and Information Technology Infrastructure (ITI) affect the Project Performance (PP), as well as to identify factors and barriers that influence the implementation of KM and ITI to support PP in Construction Consulting Companies. Seven consultants from Malaysian construction consulting companies were involved in the qualitative research process, which was blended within a case study design. Significant patterns and themes are identified and presented in this article. A conceptual research framework based on the qualitative analysis of how IT and KM support project performance is proposed. The model comprises four major components: knowledge management, ITI capability and project performance as well as factors and barriers that influence the implementation of KM and ITI capability to support project performance.

Keywords: Knowledge Management, Information Technology Infrastructure, Construction Project Performance, Construction Knowledge Areas

JEL classification: O47, O14, Q55, C88

## **1. Introduction**

The construction industry is a collection of diverse segments, products and participants that plays a central role in the national welfare, including

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the development of housing, office buildings and industrial plants as well as the nation's infrastructure and other public facilities. The importance of the construction industry lies in the function of its products, which provide the foundation for industrial production, and its impact on the national economy that cannot be measured by the value of its output or the number of persons employed in its activities alone (Barrie et al., 1984).

The construction industry is a very competitive and risky as it faces many problems such as not receiving enough cooperation, limited trust and ineffective communication that often results in low project performance. These types of problem are likely to result in construction delays, difficulty in resolving claims, cost overruns, litigation and a win-lose climate (Moore and Birkenshaw, 1998). The construction industry's problems seem to be the same all over the world. A survey reveals that about 33% of architectural/engineering projects miss cost and schedule targets. A case study indicates that costs increased by 9.2% and schedules increased to 23.3% on average for four environmental and engineering projects. A report also says that the median cost increase for design projects is about 10%. These statistics show that construction projects face major problems in achieving budget and time targets (Chang, 1997).

### ***1.1. Project Performance***

Based on the aforementioned issues and challenges stated above, various studies have been conducted to improve the performance of construction projects. In measuring the project performance (PP), performance indicators need to be identified. In recent years, significant research advancements have highlighted the typical indicators for construction project performance are cost, time and quality (Gomar et al., 2002; Feng et al., 2000; El-Rayes, 2001; El-Rayes and Moselhi, 2001; Hegazy and Ersahin, 2001; Hegazy and Wassef, 2001; Leu and Hwang, 2001; Jaraiedi et al., 1995; Ellis and Amos, 1996; El-Rayes and Hyari, 2004). Project cost is one of the main performance indicators for construction projects. The construction cost includes both the initial capital cost and the subsequent operation and maintenance costs. Each of these major cost categories consist of a number of cost components (Hendrickson, 2000). The second indicator is project time, the objective of which is to match the resources of equipment, materials and labour with project work tasks over time. Good timing or scheduling can eliminate problems due to production bottlenecks, facilitate the timely procurement of necessary materials and otherwise to ensure the completion of a project is as per scheduled. In contrast, poor scheduling can result in the waste of labourers and equipment. Delays in the completion of an entire project due to poor scheduling can also create havoc for owners who are eager to start using the constructed facilities (Gomar et al., 2002). Finally, the project quality is considered as another important concern of project owners and

managers. With the attention to conformance as the measure of quality during the construction process, the specification of quality requirements in the design and contract documentation becomes extremely important. Quality requirements should be clear, measurable and verifiable, so that all parties in the project can understand the requirements for conformance (El-Rayes and Hyari, 2004).

### ***1.2. Construction Consulting Company and Knowledge Management***

Project performance (PP) is directly affected by the management approach of the project. Most construction projects are managed by professional and independent consultants such as architects, engineers, surveyors and project managers in order to minimize the aforementioned project risks and to ensure high project performance. Construction consultants are basically selling and managing knowledge, skill and experience. They use their knowledge to manage construction projects, advise clients on the best practice and highlight critical success factors to improve project performance. There are several definitions of Knowledge Management (KM). However, the definitions can be summarized as the process of the creation, collection, organization, dissemination, and utilization of knowledge to turn an organization's intellectual assets, both recorded information (explicit knowledge) and the talents of its members (tacit knowledge), into greater productivity, new value and increased competitiveness, in order to maximize an enterprise's knowledge effectiveness and returns from its knowledge assets (O'Dell, C. & Grayson, C.J., 1998; Newman, 1997; Choo, 1998; Murray, 1998; Skyrme, 1999; Wiig 1997).

### ***1.3. Knowledge Management in Construction Consulting Companies***

Studies by Hansen et al. (1999) on KM strategies in management consulting companies found that there are several approaches in KM practices, i.e., consulting companies do not take a uniform approach in managing knowledge. Basically, there are two types of KM approaches; centralized and decentralized (Hansen et al., 1999). The decentralized approach focuses on unique problems or issues that need special and strategic solutions, whereas, the centralized approach focuses more on operational, routine or general issues.

Besides the centralized and decentralized approaches, mature consulting firms with more experience and knowledge usually adopt a codification approach where most knowledge is stored in an electronic database and is easily accessible, whereas, small and new companies mainly rely on tacit knowledge in individuals, thus applying a 'personalization'

approach. Hansen et al. (1999) found that adopting the wrong approach to knowledge management could cause serious problems in an organization, thus implying the importance of choosing the appropriate approach is crucial for the success of knowledge management implementation.

The major application of Knowledge Management in the Construction Industry was initiated by researches on Construction Knowledge Areas sponsored by the American Construction Industry Institute (CII). CII is a research organization that was formed in October 1983 with the mission of improving the competitiveness of the construction industry (CII, 2001). The knowledge areas were developed to measure the level of knowledge management implementation in the organization. The CII Knowledge Areas are shown in Table 1.

The first CII knowledge area is Front-end Planning, which is the process of developing sufficient strategic information with which owners can address risk and decide to commit resources to maximize the chance for a successful project. Front-end Planning involves pre-project planning at the corporate and project level, early estimating in project planning and risk management, and the use of modularization and pre-assembly as a tool at the project level. The second knowledge area is Design, which includes input variables and design execution against the specified expectations of the owner. In addition, the owner's expectations of the design include such criteria as cost, schedule, quality, and other expectations that are either explicit or implicit in the project objectives. The third knowledge area is Procurement which involves management of supplier and material. Effective communication with suppliers affects the smoothness of the project as well as training, implementation and documentation of construction materials. Materials management is an integrated process for planning and controlling all necessary efforts to make certain that the quality and quantity of materials and equipment are appropriately specified in a timely manner, obtained at a reasonable cost, and available when needed. The materials management systems combine and integrate the takeoff, vendor evaluation, purchasing, expediting, warehousing, distribution, and disposing of materials' functions. The fourth CII knowledge area is Construction. Construction involves control of the cost and schedule based on the project master plan and management of risk and workers at the project level. Startup and Operation is another CII knowledge area that focuses on organization of teams to ease collaboration work, especially projects with different work sites. People is another important knowledge area in the construction industry, which focuses on formal and informal training to keep employees' skills current and ensure the employees are multi-skilled in order to improve productivity. Organization is another important knowledge area that includes the establishment of organizational work structure, leaders, teams

## The Role of Knowledge Management and Information

and culture. Another CII knowledge area is Project Process, which focuses on quality management, benchmarking, identification of client's requirements and barriers. Another important knowledge area is project control, which involves management of change and work packaging

Table 1. CII Knowledge Areas

No	Knowledge Area	Component
1	Front-End Planning	1. Pre-project planning 2. Early estimating 3. Modularization/Pre-assembly
2	Design	1. Design standard 2. Design effectiveness 3. Cost effective engineering 4. Computer-aided
3	Procurement	1. Supplier relationships 2. Material management
4	Construction	1. Cost and schedule control 2. Risk management
5	Startup and Operation	3. Managing worker compensation 1. Design for maintainability 2. Planning for start-up
6	People	1. Management of education and training 2. Productivity measurement 3. Multiskilling
7	Organization	1. Project teams 2. Leader selection 3. Partnering 4. Organisation work culture
8	Project Processes	1. Quality management 2. Implementation of products 3. Benchmarking
9	Project Controls	1. Change management 2. Work packaging
10	Contracts	1. Project delivery and contract strategies 2. Use of project incentive
11	Safety, Health and Environment	1. Zero accident techniques 2. Design for safety
12	Information Management	1. Automatic identification 2. Electronic commerce 3. Fully integrated and automated project process 4. Wireless technology 5. Automation and robotics
13	Globalization Issues	1. International Standards 2. External source of knowledge 3. Knowledge protection

Source: Construction Industry Institute (2006)

including design information, material, labour, equipment, and prerequisites. Contract is another CII knowledge area and refers to project delivery, contract strategies and dispute resolution techniques. The dispute resolution techniques provide processes for addressing disputes in their early stages before they affect the progress of the work, create adversarial positions and lead to litigation. Safety, health and environment are a knowledge area that focuses on the design for safety and to achieve zero accidents. The Information Management and Technology system knowledge area comprises identification and utilization of Information technology such as specific construction software, integrated database, e-commerce, wired and wireless network. Finally, the globalization issue is also considered as an important knowledge area in the construction industry. It focuses on international standards and strategies to capture and retain knowledge in the organization.

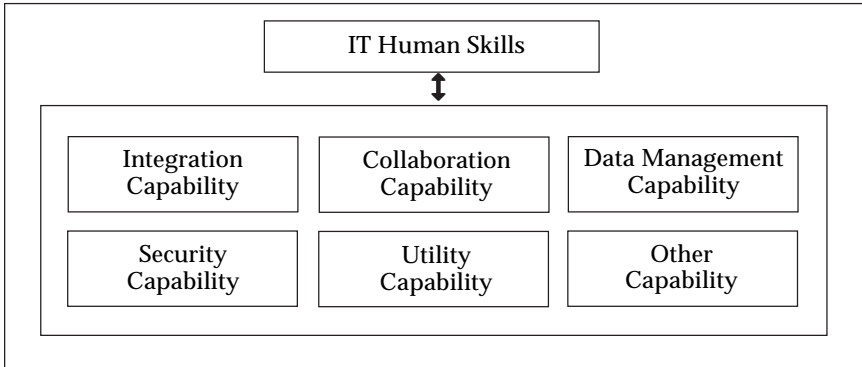
The above knowledge as specified in CII Knowledge Areas should be managed effectively. Thus, knowledge management strategy is deemed crucial to ensure that all CII knowledge areas are implemented successfully. The CII Knowledge Areas are now being adopted by a growing number of construction based companies in Malaysia (Abd. Majid et al., 2005).

#### ***1.4. Information Technology Infrastructure Capability and Knowledge Management***

Various studies show that Knowledge Management can be supported by IT Infrastructure (ITI) in managing a company's knowledge. For example, Weil and Broadbent (1998) stated that KM interacts with and is supported by IT Infrastructure capability involving network and shared groupware applications. Since Knowledge Management is about transmitting and sharing, it needs access sharing, dissemination, communication and collaboration of knowledge. To manage a company's knowledge requires a specific set of IT infrastructure and knowledge should be easily transferred through the communications network. A well-defined architecture and standard of data and applications ensures enterprise-wide compatibility of the system (Weil and Broadbent, 1998). Kim (2001) defined Information Technology Infrastructure Capability as Integration Capability, Collaboration Capability, Data Management Capability, Data Security Capability and Basic IT Services Capability as illustrated in Figure 1.

The first ITI capability is the Integration Capability, which refers to "the linking of individual IT components and services for the purposes of sharing software, communications and data resources" (Keen, 1991). The goal of integration is to ensure that technology components such as hardware, software, information and telecommunications work together seamlessly enterprise wide. The second ITI capability is the Collaboration

Figure 1. ITI Capability Concepts (Adopted from: Kim, 2001)



capability that refers to mutual efforts by two or more individuals in order to perform certain tasks. The Collaboration capability improves group working and knowledge sharing. This capability of ITI links people and allows collaboration between them beyond space barriers (Keen, 1991). The third ITI capability is the Data Management capability, which refers to the ability to manage an organization's data effectively. Data has become an important organizational resource. It is the resource shared by multiple users at different levels of management and across various functions, as well as multiple IT applications. Data Security is another key capability to be highlighted and refers to the procedures, policies, and technical configurations used to prevent unauthorized access, alteration, theft or physical damage to data and system. This became a critical issue in ITI Capability with the advent of the Internet. In a broader sense, security includes disaster management and recovery planning management (Weil and Broadbent, 1998). Another aspect of IT infrastructure capability is the common IT services to facilitate IT implementation and can be referred to as ITI Utility. For example, some capabilities such as IT planning, IT support, IT education and training to end-users are needed regardless of business type or which knowledge management model they are using. These capabilities can be considered as a utility (Weil and Broadbent, 1998). Besides the above capabilities, there are other ITI capabilities that are difficult to be categorized into a specific concept. Thus, these capabilities are categorized into Other ITI Capability. Finally, all these capabilities are combined by IT human skill to provide unique services to the organization.

## 2. Methodology

### 2.1. Respondents

The samples were identified based on references from the Malaysian Board of Engineers, Malaysian Board of Architects and Malaysian Board

Table 2. Background of the Consultants

Consultant	Position, Experience and Education	Scope of Business	Products and Services	KM or IT Initiatives
A	Senior Designer with 9 years experience and bachelor's degree	Architecture	Design Services	Integrated Network System and Latest Software
B	Architect with 12 years experience and bachelor's degree	Architecture	Design Services	Integrated Network and System Latest Software
C	Senior Engineer with 5 years experience and master's degree	Civil Engineering	Design Services Engineering Services Structure Analysis Services	Integrated Network System and Latest Software
D	Senior Engineer with 12 years experience and bachelor's degree	Civil Engineering	Design Services Engineering Services	Intranet, Server System and Latest Software
E	Managing Director with 15 years experience and Master's degree	Civil Engineering	Engineering Services Project Management	Server System and Latest Software
F	Technical Manager with 7 years experience and bachelor's degree	Quantity Surveyor	Estimation Services	Latest Software
G	Project Manager with 8 years experience and bachelor's degree	Project Management	Project Management Engineering Services Estimation Services	Integrated Network System and Latest Software

of Surveyors and further recommended by the Malaysian Construction Industrial Development Board (CIDB). The CIDB is a Malaysian government body established to focus on the development of the construction industry in Malaysia. The main criterion used for the selection of the consultants is the level of KM and IT implementation in their companies as well as their position and experience. Seven consultants with senior positions and considerable experience were selected for the

case study, comprising of architects, civil engineers, quantity surveyors and project managers. The background of the consultants is shown in Table 2. The selection of the respondents is deemed crucial to derive a practical and acceptable KM and IT approach and model to be recommended and adopted by the Construction Consulting Companies.

## **2.2. Research Design and Data Collection**

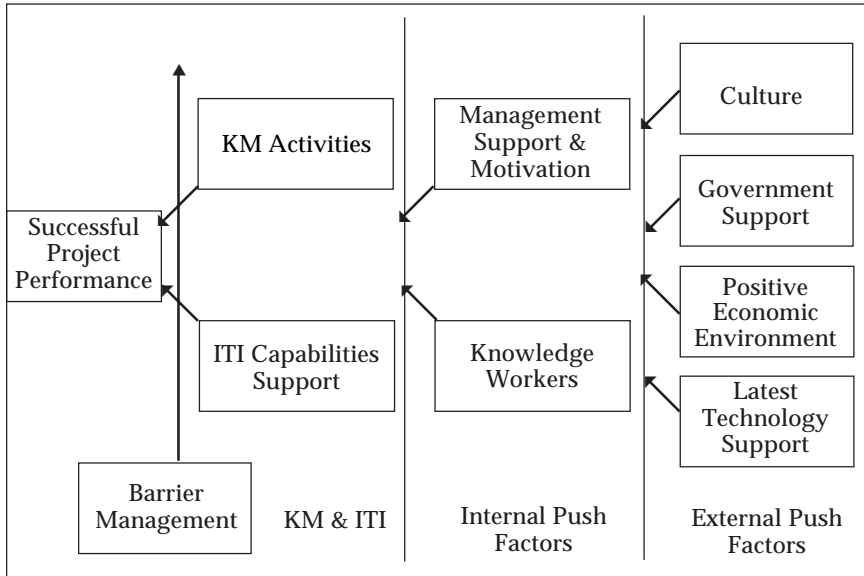
A case study was conducted to collect the information for the research. According to Orlikowski and Baroudi, (1991), this approach allows the collection of data through interviews with the consultants involved with the process, as well as through written documentation that contained stories, knowledge, experience used or written by these experts as part of the project and organizational knowledge related to KM and ITI implementation. This approach also allows the observation of the system in situ, from within the organization as the researchers were especially interested in developing the cognitive frames as well as the various political and discursive moves that are both subjective and contextual. The basic premise of an interpretive study is that all data is subjective, and one can attempt to study and analyze the data from the subject's perspective (Davidson, 2002; Orlikowski & Baroudi, 1991).

The data was collected from two main sources. First, all consultants were interviewed based on an interview protocol which comprises 31 closed and open ended questions on the key issues related to KM, ITI and PP. These interviews were conducted over a three-month period, in tandem with our analysis of archival data. Second, we examined online and offline archival data concerning the project. Most of the consultants maintained comprehensive and voluminous sets of archive. Data collected comprises company profile, project-proposal reports, project reports, policy minutes and system documentation, and promotional documents. The period covered was from 2005 to 2007, and this wide range of documents was especially useful in enabling us to understand how these consultants implement KM and ITI in their companies.

## **3. KM-ITI-PP Framework**

Based on the data collected, significant patterns and themes were identified and a framework of KM-ITI-PP was derived as shown in Fig. 2. Fig. 2 shows that KM and ITI are factors influencing project performance. However, there are internal and external push factors to be considered that influence the implementation of KM and ITI. Furthermore, barriers to the implementation of KM and ITI and management of the barriers were also identified to ensure that KM and ITI can successfully support the project performance.

Figure 2. KM-ITI-PP Framework



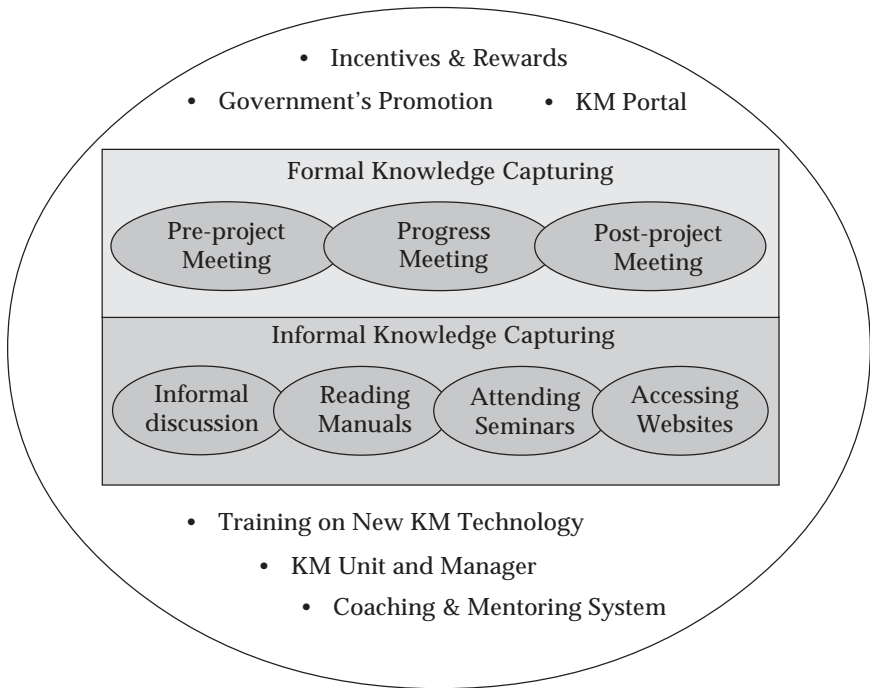
### 3.1. Knowledge Management Activities

Fig. 2 shows that Knowledge Management activity is one of the main factors influencing the success of project performance. Several knowledge management activities have been practiced among the construction players in the construction consulting industry to acquire, share and transfer knowledge among internal staff, clients, customers and suppliers. The findings show that among common KM activities include informal discussions, mentoring activities, reading supplier's manuals and documents as well as reading physical documentation and drawings to support their daily operations of consulting work. Furthermore, informal discussions and mentoring activities were found to have a positive relationship with knowledge transfer (Chang, 1997). In addition, the companies also manage their knowledge through pre-project, project progress and post-project meetings and accessing resources on the Internet. Furthermore, several companies practice other KM activities such as reading proposals and working papers, reading books, magazines, newspapers and guidelines, partners and expert discussion, accessing the associations or government bodies' website or portal as well as attending seminars and conferences.

Beside the existing practice, the study also revealed the supporting initiatives that can be implemented to promote and facilitate KM implementation in an organization. Among the initiatives are promotion

by government, exposure to KM concepts and benefits for every staff, incentives for KM initiatives, utilization of IT infrastructure, training on the technology to support KM initiatives for all staff, a portals to support KM, a systematic coaching and mentoring systems, a competitions and

Figure 3. KM Initiatives Model for Construction Consulting Industry



awards to promote KM initiatives, as well as the formation of dedicated unit and personnel to manage KM initiatives and KM Master Plan. A summary of KM activities is illustrated in Figure 3.

### **3.2. ITI Capability Support**

As shown in Figure 2, another main factor influencing successful project performance is IT infrastructure capability. Based on the data analysis, ITI facilities are categorized into integration capability, data management capability, collaboration capability, security capability and utility capability. For integration capability, the majority of the companies use email to communicate with their suppliers and clients, servers to store and share data, some of them have an integrated network system, notice board and integrated server system. For data management capability,

among the databases used in consulting construction industry are Construction Unit Rates Database, Subsurface Information Database, Developers Database, Specialists Database, Accredited Contractors Database, Specifications Database, Bills of Quantities Database and Galleries Database. For Collaboration capability, the companies uses **electronic resources sharing system**, Digital Library for technical and research journals, conference papers, academic references and technical videos. For Security software, some of the construction consulting companies in Malaysia practice backup systems, computer passwords, anti-spy ware and uninterrupted power supply. Finally, most companies implement IT training programs and establish an IT policy as part of their IT utility capability.

### **3.3. Internal Push Factors**

The findings of the qualitative analysis, as shown in Figure 2, show that management support and motivation as well as knowledge workers are the main internal push factors influencing the implementation of KM and ITI to support project performance.

#### **3.3.1. Management Support and Motivation**

Management support and motivation factors are often viewed as important factors in the implementation of KM and ITI capability to support project performance in the construction industry. Management support's primary focus is establishing a culture that respects knowledge, reinforces sharing, retains people, cultivates interaction, positive interpretation and inculcates trust and builds loyalty to the organization. Management support also focuses on establishing a knowledge infrastructure and support system that enhances and facilitates the sharing and application of knowledge at the appropriate levels.

Among the suggestions related to management support and motivation are: top management should initiate and drive the KM and ITI projects; KM and ITI implementation should be enforced in terms of policy and procedures; the organizational structure of the company should support the implementation of KM and ITI projects; management should provide incentives for staff who are involved in KM and ITI implementation; management should provide enough budget for KM and ITI projects; and management should motivate all staff to utilize KM and ITI for project performance.

Dess and Picken (1999) also highlighted that for successful KM and ITI implementation, management support and motivation must be sustained throughout the KM effort by implementing strategic vision, empowering employees at all levels, accumulating and sharing internal

knowledge, gathering and integrating external information and challenging status quo (Dess and Picken, 1999).

In addition, Greengard (1998) insists that one of the most important factors to successful KM and ITI implementation is for senior management to recognize the importance of the development of KM and ITI programmes and policies to support project performance. By funding and sponsoring KM and ITI programmes, encouraging systemic innovation and making agility a personal priority, management can achieve better performance. Additionally, top management needs to focus on and adjust the ways in which employees and teams are rewarded. Strong top management commitment is expected to support the implementation of KM and ITI for better project performance. To institutionalize the way of working and facilitate the organization's improvement efforts, management must use control and incentive mechanisms to motivate individuals to achieve desired objectives. Kirsch (2000) stated that control is exercised through mechanisms such as incentives, norms, values and recommendations to motivate and guide individuals (Kirsch, 2000).

### *3.3.2. Knowledge Workers*

In the construction consulting industries, domain knowledge workers such as consulting engineers or architects, are key users and are parts of the functional team. They form an interface between the project team and the end users during the project stage.

Based on the study, there are several suggestions to improve the knowledge of the workers: staff education level should be upgraded from time to time to increase their appreciation of the importance of KM and ITI, staff should be exposed to KM and ITI concepts and activities in order to get their support, a dedicated IT expert should be assigned to manage ITI efficiently, and inculcate positive attitudes among the staff to accept changes in the organization.

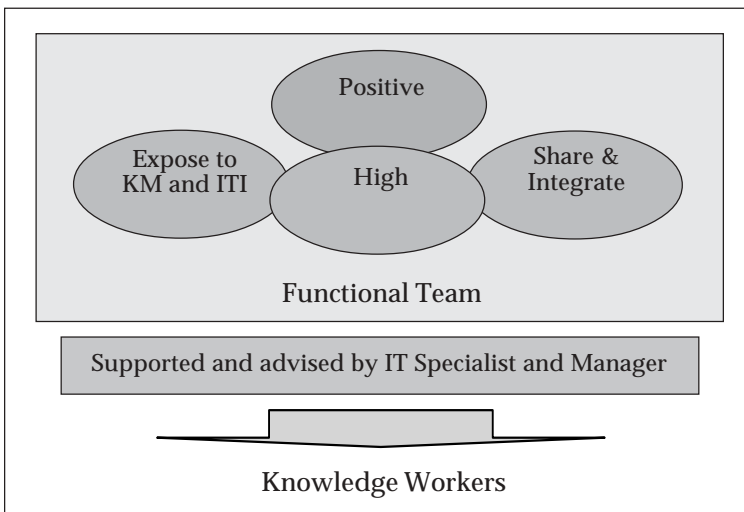
These findings are supported by the previous study done by Barki, et al. (1993) whereby effective project team members are those who are knowledgeable about technology and the business, and possess abilities to integrate their knowledge with others. They can represent the company image and directly affect the project performance. The knowledge of a project team is important as they are consultants who provide expertise in the areas in which other team members lack knowledge (Barki, et.al., 1993).

Kirsch (2000) also found that sharing and integrating knowledge across project team members is crucial for effective project management and, therefore, the recruitment of individual talent must be combined with team-building efforts. Users should be part of the project team. Users play a critical role in furnishing knowledge to the project, exercising control and providing leadership to the project. Ignoring or minimizing the role

of the user is likely to impede project progress and have negative repercussions on project outcomes (Kirsch, 2000).

The findings also found that successful implementation of ITI and KM in the construction consulting industries also demands a knowledgeable IT manager as well as IT specialists who should be part of the project team in the implementation of KM and ITI. With strategic ITI knowledge, the IT team can play a role in the strategic decision processes for the project and may support monitoring of the project. Strategic IT knowledge workers can plan and manage an organization, IT infrastructure and handle IT actions of the competitors and the potential of emerging technologies for an organization's business (Armstrong and Sambamurthy, 1996). An IT manager with extensive strategic IT knowledge should be able to advise top management on IT issues such as investment in appropriate technologies, including the right IT tools to adopt, investment timing and scope of the implementation within the organization. IT specialists are often involved in requirement studies, systems selection, systems configuration, installation of hardware and software as well as prototyping and data migration. With their enhanced roles in systems configuration, the role of IT specialists is of particular importance in the

Figure 4. Model of Knowledge Worker for Construction Consulting Industry



data migration activity where data from old systems has to be loaded into the new systems with suitable modifications (Govindaraju et al., 1998). IT specialists should also advise the construction management staff of the latest software available on the market and its suitability with the organization's business needs. The model of a knowledge worker is illustrated in Figure 4.

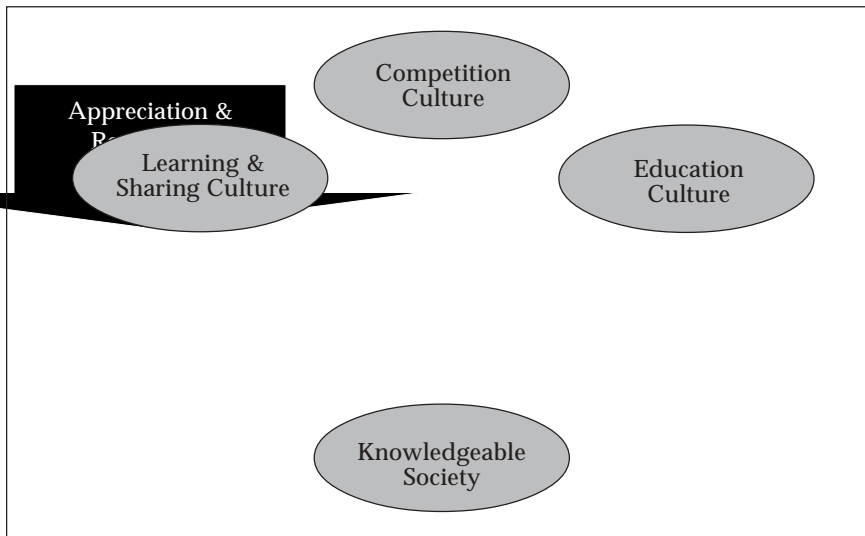
### 3.4. External Push Factors

Besides the internal push factors, there are four external push factors that influence the implementation of KM and ITI in the support of successful project performance, as shown in Figure 2. The external push factors are positive culture, government support, positive economic environment and latest technology support.

#### 3.4.1. Positive Culture

Based on the above qualitative study, it is found that a positive culture can improve project performance. The study has identified three cultures that should be cultivated in the organization. First, a learning and sharing culture that encourages staff to share knowledge, learn new things and improve the existing routine works based on the new knowledge. Second, a competition culture in which staff are encouraged and rewarded whenever they contribute to the knowledge network. Third, an education culture where long life learning and continuing study is encouraged, thus, increasing the education level of the staff. Finally, the above culture will

Figure 5. Positive Culture



create a knowledgeable society where expertise is appreciated and rewarded, thus, contributing to the successful implementation of KM (O'Dell and Grayson, 1998). The summary of the above knowledge culture is illustrated in Figure 5.

Furthermore, according to Gidden (1984), humans creatively construct the social systems in which they live. This implies that users of knowledge management systems will creatively reshape the environment

according to the unique characteristics of their culture. Furthermore, Scarborough et. al., (1999) stressed the important role of human resources and the need to develop and build a knowledge sharing culture. Larson (1999) argues that it is vital for companies to first consider the cultural environment before implementing a KM initiative. In other words, a company wishing to capture the knowledge of its employees must cultivate a culture that encourages teamwork and knowledge sharing.

Furthermore, organizations need to enable their staff to capitalize on their individual knowledge and share the knowledge and information with others. Research reveals that a major challenge for achieving this lies in promoting cultural change in organizations (Dhillon, 2001). Moreover, Kotter and Heskett's (1992) study on corporate culture and performance stated that corporate culture has a significant impact on a firm's long term economic performance and the success or failure of firms. Thus management should exert more effort to create a corporate culture in order to be more competitive.

#### *3.4.2. Government Support*

Figure 2 shows that government support in the form of policy as well as tangible and intangible incentives, is another important factor that can influence the implementation of KM and ITI among construction consulting companies. A study on KM in China revealed that government-sponsored economic and social reforms have encouraged domestic knowledge creation in terms of both research and development activities in Chinese universities and entrepreneurial activities in the business sector (Burrows et. al, 2005).

Another study done by Cohen (1998) revealed that the US government has emphasized the collection, distribution, reuse and measurement of existing codified knowledge and information in the US. This creates an environment where workers are expected to capture the essence of their experience, decide what is relevant and, hence, worth codifying, and spread it throughout their organizations

#### *3.4.2. Positive Economic Environment*

Analysis of data also found that a positive economic environment is one of the external factors affecting the implementation of KM and ITI to support project performance. Based on the findings, to create a positive economic environment, new knowledge and technology should be employed in the process. This demands the construction players to improve their business strategy with new knowledge and technology to allow them to be more innovative and competitive.

The aforementioned finding is supported by previous research where it is found that in the knowledge-based economy, future success will be

based more on the strategic management of knowledge compared to the strategic allocation of physical and financial resources (Bonora and Revang, 1993; Bontis, 1998). Castells (1990) identified the emergence of a new “informational mode development” where information is as central to economic success as productivity and energy usage were in the previous eras. If there is one distinguishing feature of the new economy that was developed as a result of powerful forces such as global competition, it is the ascendancy of intellectual capital. To succeed in the economy, organizations and individuals need to both accept and adapt to an environment where intangible assets are a key driver in the economy. They need to develop new processes, cultures and behaviours that encourage the creation of new knowledge, the sharing of existing experience and know-how and the efficient utilization of those assets for mutual benefits of all (Oxbrow and Abell, 2002).

Essentially, the investment decisions in the construction industries are conceived to meet market demands. Various possibilities may be considered in the implementation of KM and ITI initiatives in the firm. Economic feasibility of each alternative will be assessed and compared in order to select the best possible KM programme and ITI infrastructure investment to support project performance.

#### *3.4.3. Latest Technology Support*

Based on Figure 2, the latest technology support is found to be one of the important external factors facilitating KM and ITI support of project performance. The demand for a more technology-based systems approach to manage construction projects, including planning, design, construction, maintenance and rehabilitation, has motivated significant advances in the development of construction-related software. The technology-based system not only increases the automation of the work processes, but at the same time facilitates the knowledge management activities throughout the whole project life cycle. Based on the interviews, the consultants focus on the establishment of an Information and Technology network and server to support the system; the establishment of a databases system to facilitate knowledge archiving and sharing (especially for the previous projects: design, analysis, documentation etc); utilization of latest application software such as software for technical drawing and design, Bills of Quantity (BQ) and project management; and utilization of communication tools such as portal, email or websites for collaboration activities.

The findings are supported by previous research by Duffy (2000) whereby the most valuable role of technology in the construction industry is in enhancing the speed of knowledge transfer. IT enables the knowledge of the individual or group to be extracted and structured, and then used by other members of the organization (Duffy, 2000). Furthermore, most

organizations capture a significant amount of data in highly structured databases (Frank et. al., 1999). In addition, the core value activity around business data is the ability to analyze, synthesize and then transform data into information and knowledge. Information is the outcome of capturing

Table 4. Construction Management Technology Tools

No	Construction Technology tools	Components
1	Hardware Technologies	<ul style="list-style-type: none"> <li>o Integrated Network System</li> <li>o Integrated Server System</li> <li>o Backup System</li> <li>o Uninterrupted Power Supply</li> <li>o Security System</li> </ul>
2	Software	<p>Design Software. Example:</p> <ul style="list-style-type: none"> <li>o AUTOCAD for technical drawing</li> <li>o Adobe Photoshop for design</li> <li>o 3D-Revit for 3D design</li> <li>o Staadpro &amp; Strap for structural drawing</li> <li>o Structural analysis &amp; design software (ETABS, SAP 2000, STAAD Pro, ADAPT)</li> <li>o ESTEEM - a reinforced concrete structural analysis, design</li> <li>o PROKON - a complete package of structural design and analysis software</li> <li>o RAD - Rigid Airfield Design (RAD)</li> </ul> <p>Project Management Software. Example:</p> <ul style="list-style-type: none"> <li>o Microsoft Project for project management</li> <li>o Accounting System for financial management</li> <li>o Primavera for project management</li> </ul> <p>Cost Management Software. Example:</p> <ul style="list-style-type: none"> <li>o Integrated Cost Management System (CMIS) for BQ management</li> <li>o MCACES - Gold - Micro-computer Aided Cost Engineering System</li> </ul> <p>Simulation &amp; Modelling Software. Example:</p> <ul style="list-style-type: none"> <li>o Multiple reservoir operation simulation models software</li> <li>o PDS (Highway, Infrastructure &amp; Ground Modelling)</li> <li>o Plaxis (2D and 3D Finite Element)</li> <li>o SAFE 2000 (Soil-Structural Finite Element)</li> <li>o MIKE 11 (River Modelling Software)</li> <li>o Digital photographic equipment</li> </ul>

## The Role of Knowledge Management and Information

		<p>Knowledge Based, Automation &amp; Analysis Software. Example:</p> <ul style="list-style-type: none"> <li>o Geotechnical and water resources software (GEOPRO)</li> <li>o Steady and unsteady state open channels network hydraulic analysis software</li> <li>o Water reticulation network analysis software</li> <li>o Water hammer analysis software</li> <li>o Hydrological models software</li> <li>o WaterCAD - a complete water distribution analysis and design tool</li> <li>o GPS systems</li> <li>o SHOCK - Blast load analysis program to calculate the impulse and pressure on blast surface</li> <li>o NONLIN V 1.0 - Structural Dynamical and Earthquakes Engineering Analysis program</li> <li>o FRANG - Calculates gas pressure inside a room generated from internal explosion</li> </ul>
	Databases	<ul style="list-style-type: none"> <li>o Construction Unit Rates Database</li> <li>o Subsurface Information Database</li> <li>o Developers Database</li> <li>o Specialists Database</li> <li>o Accredited Contractors Database</li> <li>o Specifications database</li> <li>o Bills of Quantities database</li> <li>o Galleries database</li> </ul>
3	Collaboration Tools	<ul style="list-style-type: none"> <li>o Email System</li> <li>o Notice/Bulletin Board</li> <li>o Electronic meeting systems</li> <li>o Video-conferencing</li> <li>o GroupWare</li> <li>o Electronic bulletin boards</li> </ul>
4	Intelligent Tools	<ul style="list-style-type: none"> <li>o Decision support tools using neural network.</li> <li>o Virtual reality.</li> <li>o Genetic algorithms</li> <li>o Intelligent agents</li> <li>o Internet search engines</li> <li>o Knowledge mapping</li> </ul>

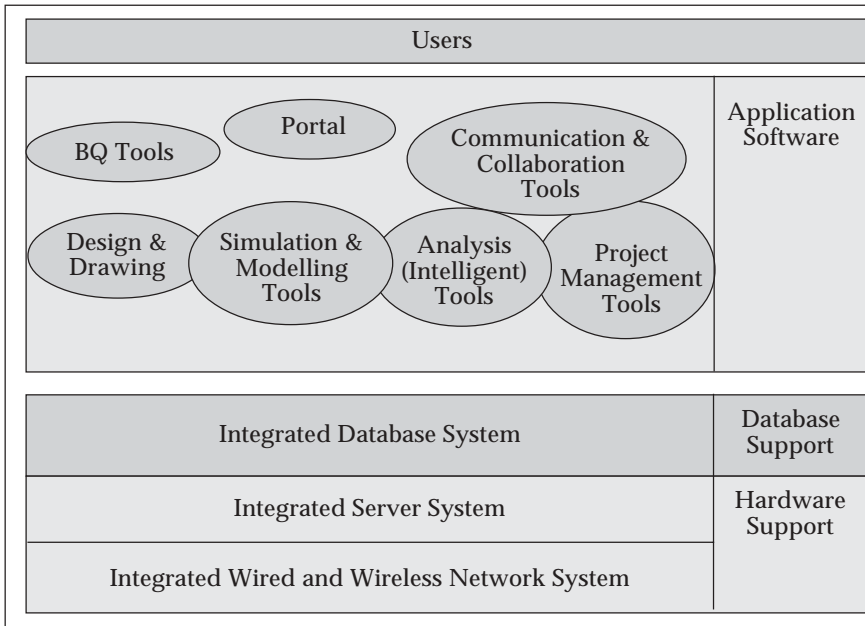
and providing meaning to the data. Information is typically stored in semi-structured content such as documents, e-mail, voice mail and multimedia (Liebowitz, 2000; Hubbard, 1998). Table 4 shows a combination of technologies used in the construction industry, based on the qualitative findings and technology components identified by Chapman et al. (2001).

### **3.5. Barrier Management**

As shown in the KM-ITI-PP Framework (Figure 2), the implementation of KM and ITI to support project performance depends on internal push

Finally, the summary of the above technology support is illustrated in Figure 6.

Figure 6. Latest Technology Support for Construction Consulting Industry



factors (management support and motivation and positive knowledge workers) and external push factors (Culture and Government Support, economic and technology). However, there are several barriers to the implementation of KM and ITI. Before an organization can achieve project performance goals through the support from a successful KM and ITI, the company must understand the barriers to KM and ITI and develop methods in their planning to manage and overcome them. The findings show that the main barriers to the implementation of Knowledge Management in Malaysian Construction Consulting Companies are not enough time, lack of money, lack of management support, lack of team working culture among the consultants, lack of willingness to share problems, misunderstanding of KM concepts, culture and political interference, lack of staff readiness and lack of expertise.

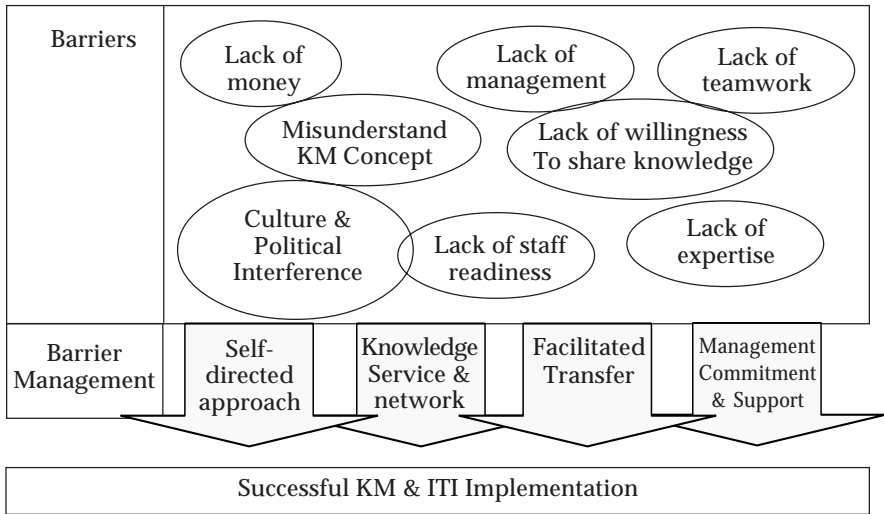
Previous studies have identified several approaches to manage aforementioned barriers. O'Dell and Grayson (1998) presented three approaches to manage barriers. The three methods include self-directed, knowledge services and networks, and facilitated transfer. Each approach builds on the other and can counter different barriers. The self-directed method helps to counter the problem of others not knowing that the knowledge already exists in the organization. The approach focuses on

capturing information and making it available for others to use. The employees access the knowledge base's repository to get the information they need, when they need it. This method can also include systems that direct the user to someone who can help them. An example of this method is a Yellow Pages system that basically serves as a map or directory of expertise or 'who knows what' in the organization. The next method of knowledge services and networks expands on the self-directing approach. According to O'Dell and Grayson (1998), "knowledge managers and knowledge integrators add value by scanning the flow of information, and organizing or 'packaging' knowledge into more digestible and applicable format". Another key aspect of this approach is the use of groups getting together to share knowledge and learn from each other. The last approach introduced by O'Dell and Grayson (1998) is facilitated transfer. The facilitated transfer approach makes designated personnel responsible for assisting others in the knowledge sharing process. It includes the functions from the other two methods and adds a dedicated team to facilitate the process. This approach facilitates building the relationships to get people to use knowledge from others and it aids in providing the motivation needed to use the knowledge (O'Dell and Grayson, 1998).

Garvin (1998) recommended another approach to manage the aforementioned barriers is to open up an organizational boundary to allow information flow. The organizational boundary should be opened up to allow information flow. Several strategies such as conferences, meetings, and project teams, which either cross organizational levels or link the company and its customers and suppliers, can ensure a fresh flow of ideas and the chance to consider competing perspectives (O'Dell and Grayson, 1998).

Finally, with regards to the lack of management involvement and support, the organization should create an environment for the management to give their commitment and support, such as regular meetings between employees and managers. In the meeting, the employees' present methods to improve their business processes and their managers must make a decision whether or not to implement the recommendation. This process encourages management support and helps the organization to create a learning environment. Furthermore, a reward system should be established to illustrate the management appreciation of the efforts. This type of event helps keep management involved in the knowledge sharing process and will ensure the success of the programmes (Stewart, 1997). A summary of the above barrier management is illustrated in Figure 7.

Figure 7. Barrier Management in KM and ITI Implementation in Construction Consulting Company



#### 4. Conclusion

This article address the issues of Knowledge Management (KM) and IT infrastructure (ITI) contribution to project performance (PP) in the construction consulting industry as well as other factors and barriers that affect the implementation of KM and ITI to support PP. The link between knowledge management, IT infrastructure and project performance was conceptualized in a way that allows knowledge Management, IT infrastructure barrier management and other factors contribute to project performance by the provision of improved quality, schedule delivery and lowered cost throughout the project cycle.

To summarize, the aforementioned findings provide a guiding principle for Knowledge Management and IT infrastructure to facilitate Project Performance through the understanding of KM and ITI contribution to project performance. Furthermore, the findings also address the internal and external factors as well as barriers to ensure the success of the implementation. Thus, the management of Construction Consulting Companies should take advantage of the current positive perception and movement towards the implementation of Knowledge Management and IT infrastructure to support Project Performance. Policy, expertise and culture development related to Knowledge Management and IT infrastructure needs further attention as an important support factor to the implementation of Knowledge Management and IT infrastructure in the companies. Furthermore, a conducive learning environment in the form of awareness programs, formal and informal training as well as seminars,

conferences and exhibitions should also be given greater emphasis. Therefore, it is recommended that Construction Consulting Companies should develop strategies for reviewing organizational policy and culture to stimulate the implementation of Knowledge Management and IT infrastructure to facilitate project performance. As such, government bodies, together with companies, should work together to derive methodologies and approaches to facilitate the creation of a Knowledge and IT environment in consulting companies.

There are many areas that warrant further studies. For the present study, the respondents were chosen from Construction Consulting Companies. Further comparative researches may be conducted across different industries and sectors such as manufacturing, utility, agriculture. Another possible study can be carried out on the private and public sectors in Malaysia. Applying the conceptual model to the manufacturing sector or public/private institutions will provide further understanding on the impact of the internal and external factors identified from this study, as the core business and orientation may differ from that of a construction consulting company. Consequently, comparisons among different industries can help to understand the pattern of KM and ITI strategies implemented, so that the interplay between KM, ITI and PP could be more comprehensively understood. In addition, the cross-cultural comparisons can provide better understanding on the influence of the socio-cultural interactions on the development and implementation of KM and ITI to support PP.

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