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THE MEASUREMENT FACTOR OF EMPLOYEE PARTICIPATION FOR KNOWLEDGE MANAGEMENT SYSTEM IN ENGINEERING CONSULTING FIRMS

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Abstract. Knowledge Management Systems (KMS) is a fundamental tool in the implementation process of Knowledge Management (KM), which is used to manage knowledge of information technology systems in an organization. However, a well-developed KMS should not only take advantage of information technology function, but also require the development of a complete measurement system for KMS. The purpose of this research is to develop an employee participation framework to describe the cause-effect relationship of KMS. Three case studies were interviewed for building measurement factors of KMS used by engineering consulting firms. Two questionnaires were sent to managers of engineering consulting firms for establishing main factors and sub factors in the measurement system in which four primary objectives were identified as "Activity in forum", "Statistic of knowledge system", "Participation of KM activity", and "Number of documents". The cause-effect relationship among four objectives was shown by path analysis.

Keywords: Knowledge Management Systems (KMS), engineering consulting firms, employee participation, case study.

Introduction

Ever since scholars first introduced the concept of Knowledge Management (KM) (Nonaka, Takeuchi 2007), applications of KM in facilitating and managing innovation and organizational learning have become an important issue (Choi, Lee 2003; Goh 2006; Ling, Gui 2009; Yu *et al.* 2009; Tserng *et al.* 2010; Lin, Lee 2012; Wu *et al.* 2012). Knowledge management includes the processes of creating, securing, capturing, coordinating, combining, retrieving, and distributing knowledge (O'Dell, Grayson 1998; Group 1999; Bhatt 2001; Tserng *et al.* 2010). Having processed previous information and knowledge, engineers and experts can reuse and share data to reduce the time and cost involved in solving a current problem. Knowledge management is particularly attractive to the construction industry because of its competitive environment and low profit margins (Tserng, Lin 2004; Carrillo, Chinowsky 2006; Tserng *et al.* 2010; Lin, Lee 2012; Wu *et al.* 2012).

In the construction industry, general contractors and engineering consultant firms continually plan, implement, and use KM for translating tacit knowledge into explicit knowledge and enhancing the performance and capabilities of their resources (Carrillo, Chinowsky 2006; Lin *et al.* 2006; Tseng 2008a; Yin *et al.* 2008; Lin, Lee 2012; Wu *et al.* 2012). Tacit knowledge is hidden, not easily articulated, and is usually considered to be derived from experience. This kind of knowledge contains records of submissions, replies, and additional responses from the forum and the SOS system. Explicit knowledge is that which is expressed rather precisely and formally, and is often readily available through books, memos, manuals, etc. Explicit knowledge includes records of the final solutions in a forum and the documents created by retired employees (Tserng, Lin 2004; Lin *et al.* 2006; Yin *et al.* 2008). Knowledge Management Systems (KMS) is fundamental tools in the implementation of KM, which is designed to use and reuse information for solving problems (Quaddus, Xu 2005; Lin, Lee 2012).

Based on the availability of information technology, KMS can support the innovation, storage, retrieval, transfer, and application of organizational knowledge (Alavi, Leidner 2001). Knowledge creation, coding, and distribution are necessary functions of KMS (Bowman 2002). The objective of a KMS is to collect, use, and reuse useful knowledge for solving a problem and improving work performance (Tuzovsky, Yampolsky 2003; Tseng 2008b). A well-developed KMS should not only take advantage

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of information technology but also of cultural change, rewards, and executive teams (Chang, Li 2007; Du Plessis 2008; Yu *et al.* 2009; Ding *et al.* 2011).

No matter how much effort upper management invests in a KMS, implementing the highest levels of KM still requires employee participation. Managers should have a preliminary understanding that employee participation would facilitate KM activities (Tseng 2008a; Tserng *et al.* 2010). However, limited research has been conducted on employee participation in KMS using a systematic approach. Hence, this research paper aims to establish a methodology for measuring the degree of employee participation.

The objective of this research is to explore the measurement factors of KMS from the employee point of view. We developed an employee participation framework to describe the cause-effect relationships within KMS. The framework identifies principal factors and analyzes the cause-effect relationship for employee participation in KMS. Our methodology involved using three case studies to build measurement factors of KMS, and two questionnaires to establish objective factors and subfactors in measurement factors of engineering consulting firms. Discussion of cause-effect relationships among the objective factors was shown by path analysis.

1. Knowledge management and knowledge management systems

There are several challenges for the implementation of knowledge management in construction, such as short supply times, organizational culture, lack of standard work processes, and insufficient funding. More specifically, these barriers manifest themselves in a lack of managerial support, employee resistance to knowledge sharing, poor information technology infrastructure, lack of a real-time integrated database, and inadequate cash flow (Carrillo, Chinowsky 2006). The control points of KMS in the stages of execution, evaluation, and reinforcement of KM include the system usability and effectiveness, the number of knowledge objects, progress reports, user satisfaction, knowledge object application count, usage count, appraisals, review mechanisms, portal maintenance, and process tuning (Chang, Li 2007).

Therefore, construction is a project-based industry, which makes the continuation of knowledge difficult (Tserng, Lin 2004; Lin *et al.* 2006; Tserng *et al.* 2010). It also makes the management of knowledge and the extension of experience essential. How to transform implicit knowledge into explicit knowledge is, therefore, a principal subject. Engineering consulting firms in charge of planning, designing, and supervising construction projects are knowledge-intensive businesses (Mortazavi 2010; Ding *et al.* 2011). Most of the knowledge assets are mentally retained in the minds of senior engineers or in masses of documents. Traditionally, the gathering of knowledge is through reading documents or through oral communication between employees. However, loss of knowledge by the resignation of senior engineers can result in loss of the competitive edge (Yu *et al.* 2009, 2012; Ding *et al.* 2011; Lin, Lee 2012). Thus, it becomes critical to increase the productivity of engineers and to reduce the impact of staff attrition. The KM activities include the processes of creating, capturing, storing, sharing, and reusing knowledge. These processes are viewed by engineering consulting firms as a fundamental basis for competition. Previous research on KM had only focused on the performance evaluation of KMS (Teh, Yong 2011; Lin, Lee 2012; Yang *et al.* 2012).

There are three critical factors influencing KMS performance: its strategy, planning, and implementation. The strategy of Knowledge Management is affected by the degree of both internal and external analysis. The planning of Knowledge Management is affected by goal setting, employee training, and technique requiring. The implementation of Knowledge Management is affected by employee commitment and the measurement system. Moreover, developing a complete measurement system for the KMS becomes an essential issue (Lin, Tseng 2005; Tseng 2008b). This research focuses on the critical factors involved in the implementation of KM and establishes a measurement system framework for employee participation.

2. Research design and methodology

The literature describes several critical factors affecting KMS performance, however, not all of these are relevant to the construction industry. Hence, for this research, we statistically analyzed case studies in order to examine which of the KMS factors are present in engineering consulting firms.

A case study methodology was adopted in order to gain a detailed insight into senior manager participation in KMS. This research selected three large engineering consulting firms to gain a perspective on how KM is used in the industry. For each firm, the person with overall responsibility for the KMS and employee participation measurement factors were gleaned through interview. The interviews were transcribed and returned to engineering consulting firms in order ensure the accuracy of transcript. Even if the studies on KMS in general are remarkable, their specific application in engineering consulting firms is not identical to that in other industries (Tserng, Lin 2004; Tseng 2008a; Tserng *et al.* 2010). In order to establish a precise and quantitative process for building measurement factors, we used two questionnaires.

An independent-sample T-test was used in the questionnaire analysis to identify both significant and non-significant factors. This is a method of quantitative analysis used to compare mean values of two samples to determine the likelihood that the samples are from similar populations, but with different mean values. When two samples are taken from the same population, it is very unlikely that the means of the two samples will be identical. The T-test compares the mean scores of two groups on a given variable (Peterson 1994; Henson 2001; Zhang 2006; Brown *et al.* 2007). The analysis was used to describe the variability of the significant factors within the population. On the other hand, the path analysis method is used for verifying the theoretical model (Wright 1921, 1934; Pett *et al.* 2003; Brown *et al.* 2007; Huang, Hsueh 2007; Lin, Kuo 2007).

The first questionnaire was explored by correlation analysis and was used to check the linear relationship between factors, which constituted the basic assumptions of path analysis (Wright 1921, 1934; Demian, Fruchter 2006; Huang, Hsueh 2007). Thus, the degree of correlation is first confirmed through correlation analysis, and the cause-effect relationship is then confirmed through path analysis in the second questionnaire.

As a result, the first questionnaire is directed from the perspective of engineering consulting firms, to establish the factors affecting construction industry. Through statistical analysis, significant factors were filtered and screened. The purpose of the second questionnaire is to explore the correlation between these common factors. Further, the use of method validation and path analysis allowed exploration into the cause and effect relationship between the statistical probabilities (Brown *et al.* 2007). This article employs a quantitative approach to establish measurement factors for employee participation in KMS. Engineering consulting firms may refer to this study when implementing KMS, so as to improve KMS application efficiency and to avoid implementation failure.

3. Case study

To obtain a representative sample in the case study, all engineering consulting firms that were chosen had to have an already implemented KMS. In each company, three managers in charge of implementing KM were interviewed, which provided the basis of the case studies on how companies establish KMS. The interviewees followed three main themes: (1) the strategy behind the use of KM at their firm (Demian, Fruchter 2006; Yu *et al.* 2009); (2) the framework of their implemented KMS (Lee, Hong 2002); and (3) the system of measurement in their KMS (Lin *et al.* 2006; Tseng 2008b; Yu *et al.* 2009; Lin, Lee 2012). All of the case study firms are categorized as large engineering consulting firms of more than 1000 employees (Carrillo, Chinowsky 2006). Moreover, these companies had invested heavily in information technology before implementing Knowledge Management Systems (Lee, Hong 2002). The scope of the projects in the case study is illustrated in Table 1, and the summary of the findings of the KM and KMS in the engineering consulting firms are shown in Table 2.

3.1. Engineering consulting firm A (ECF-A)

ECF-A has more than 1300 engineers. Knowledge Management has been implemented since 2001. The ECF-A

Table 1. The scope of projects undertaken by engineering consulting firms in case study

No.	The scope of projects
ECF-A	Electric power, water conservation, urban construction, industry and agricultural construction, environment, civil engineering, transportation, building, machinery, and electricity.
ECF-B	Railroads, highways, bridges, tunnels, ports, airport, metro, water conservation, urban planning, land development, environmental protection, and factory construction.
ECF-C	Oil refining, petrochemical, chemical engineering, electricity, steel, transportation, incinerator, infrastructure, and environmental engineering.

Table 2. The summary for KM and KMS of engineering consulting firms in case study

No.	The strategy of Knowledge Management	The framework of Knowledge Management System
ECF-A	To establish an employee-oriented system, which manage documents in KMS. To help engineers establish knowledge search engine, and reduce the operating time massively in project. To reserve and classify historical information from company.	Information acquisition Information value adding Building the knowledge framework Integrating the wisdom
ECF-B	To establish a specialized knowledge base, that has a good classification system, and that supplies each kind of domain knowledge for storage and use. To establish a knowledge community for supplying knowledge communication and collaboration for problem-solving.	Professional knowledge center Knowledge community
ECF-C	To transform knowledge within the operations of enterprise, and use information technology and management skills for accumulating, sharing, and updating knowledge capability.	Knowledge base Knowledge experts Knowledge community E-learning system Links

Defined knowledge to include CAD files and Engineering Reports. This reference to knowledge focused on explicit knowledge. The main strategy in ECF-A was to establish document management. Therefore, the company stores all records when executing KM for analyzing explicit knowledge out of tacit knowledge on the basis data collected. Data mining is the next project in the post-implementation of KM. ECF-A has four levels in its KMS: "information acquiring", "information value adding", "building the knowledge framework", and "integrating the wisdom".

At the information acquiring level, information is input into the system, and the output material is the enterprise or work process. Information acquired by ECF-A included engineering reports, CAD files, ISO standards, and external data. All materials followed ISO standards and were stored in knowledge bases.

At the information value adding level, ECF-A introduced several techniques to assist information value adding to help engineers find information without leaving an operating job. These techniques were document scanning, image processing, database, and full text retrieval. These techniques not only processed all material information, but also established tagging and indexing in the database. This level translated non-structural information into structural information. At the same time, this level added safety information, information usability, as well as user authority management.

In building the knowledge framework, the next step was to supply a useful query interface, a reusable function, and a friendly viewer. This level assists engineers in transforming information to knowledge easily and efficiently, as well as in setting up the suitable authority.

In integrating the wisdom, the engineering consulting firm requires that its engineers coordinate when solving problems. When engineers are required to express problems systematically and solve them in the same manner, knowledge becomes wisdom. The function of the KMS is to include coordination, discussion forums, knowledge recommendations, and e-learning in ECF-A.

3.2. The engineering consulting firm B (ECF-B)

ECF-B employs more than 1000 engineers. Knowledge Management was implemented in the year 2000. ECF-B defined knowledge to include personal experience, technique reports, handbooks, and program source code. However, this definition of knowledge makes it difficult to draw a distinguishing line between tacit knowledge and explicit knowledge. Developing a knowledge map is the next step in the post-implementation of KM; this involves establishing connections among documents, allowing employees to find information in the KMS more easily. In order to evaluate employee participation after implementing the KMS, ECF-B demanded to establish factors of measurement for employee participation in the KMS. The structure of the KMS used by ECF-B included "the specialized knowledge base" and "the knowledge community".

The specialized knowledge base had a well-designed classification structure, which included a technically-based and content-based structure wherein explicit knowledge could be stored and reused. The classification structure also reduced the repeated effort of sharing knowledge across different organizations.

The knowledge community supplied a mechanism for knowledge communication and collaboration in tacit knowledge. The functionalities of the knowledge community for users included a submit and reply topic and a search and sort by classification. The functions of the manager included setting and maintaining the knowledge published as well as classifying, deleting, and expert grouping it.

3.3. The engineering consulting firm C (ECF-C)

ECF-C employs over 5000 engineers. Knowledge Management was implemented in 2005. ECF-C defined knowledge to include patents, engineering technology, and reputation. This company solely stored knowledge into the knowledge base as its significant strategy in research; moreover, there is a chance for the raw data and the unprocessed information to become knowledge for storage because ECF-C considered knowledge to be applicable across all cases whilst raw data and unprocessed information to be more case specific.

The framework of its KMS included five components termed as "Knowledge Base", "Knowledge Experts", "Knowledge Community", "E-learning system", and "Links".

The Knowledge Base includes Knowledge Documents, Cyclical Information, and Historical Information. The Knowledge Documents component classified documents into four categories: profession, industry, project management, and corporate management. Cyclical information includes current information such as news, financial information, announcements, monthly reports, journal papers, projects, and catalogues. Historical information includes final reports, enterprise information, company information, collection reports of best practice, and practical experience reports.

The Knowledge Experts contains classified information and builds the experts contact list and profiles. The contact list assists engineers in finding the appropriate internal, external, and retired experts related to the company.

The Knowledge Community gathers engineers with similar interests to collectively share their engineering experiences. The original knowledge community focused on value engineering. The community found a solution and was able to reduce the costs of the project through brainstorming.

The E-learning system is integrated into the KMS used by ECF-C. Teaching material was found to be capable of referencing and querying within the E-learning system, which facilitated the reliability and regularity of knowledge transfer.

Links refers to the component used to connect the internal knowledge within the company's external knowledge bases that comprise government organizations, academic organizations, and A/E/C industry.

3.4. The measurement factors of the case study

Following the case study, this research summarizes the interviews and literature and then constructs 37 measurement factors of employee participation in the KMS. Eleven measurement factors were found in ECF-A, 25 in ECF-B, and 19 in ECF-C. The main strategy of KM in ECF-A is document management in the KMS; hence, there were fewer observed measurement factors. ECF-B had established a knowledge base and a knowledge community, and therefore, held the largest number of measurement factors. Although ECF-C's KMS framework was larger than ECF-B's, it only stored knowledge into its Knowledge Base without raw data and added information. Thus, ECF-C ended up with fewer factors than ECF-B. A detailed description of factors is shown in Table 3.

4. Questionnaires' survey

This research used two questionnaires for evaluating and analyzing the discovered measurement factors. These factors in the pilot survey and final survey had used a Likert-Type Scale. The scale ranged from 1 to 5 (with "1" being "not significant", "2" being "fairly significant", "3" being "normal significant", "4" being "significant", and "5" being "very significant") (Zhang 2006). To measure employee participation in KMS, all samples of these questionnaires focused on managers in engineering consulting firms.

4.1. Pilot survey and factor analysis

In the pilot survey, 104 questionnaires were sent, with 57 responses. There were 4 potential respondents who were unable to fill out this questionnaire. The effective response rate was 50.96%. The pilot survey questionnaire that was designed for this research consisted of two parts, including (1) a manager profile, and (2) the 37 factors for employee participation in KMS. By independent samples of the T-test, this research removed five non-significant factors: factors 3, 5, 6, 11, and 12. The other 32 significant factors remained after factor analysis.

Factor analysis was found to be a useful statistical method for describing the variability among measurement factors. The Kaiser-Meyer-Olkin (KMO) test and Barlett's test were used to measure whether the sampling adequacy analysis was a factor for comparing the magnitudes of the observed correlation coefficients to the magnitudes of partial correlation coefficients. A value greater than 0.5 was the threshold for a satisfactory factor analysis to proceed (Pett *et al.* 2003; Zhang 2006; Yuan *et al.* 2010). The results of this research are shown in Table 4.

Figure 1 illustrates the scree plot of the factor analysis of employee participation. The four principal components were extracted by specifying a minimum initial eigenvalue of 2. The pilot survey established 32 factors and extracted 4 principal factors for Employee Participation in the KMS. Each of the four principal factors included eight sub-factors. As a result, this research used Cronbach's Alpha internal consistency coefficients test, which is the most commonly used for Likert scale surveys (Henson 2001). The analysis showed that Cronbach's Alpha for the four principal components were well above 0.5 (including 0.806, 0.827, 0.723, and 0.676), therefore the reliability of all principal components could be assumed (Peterson 1994). As shown in Table 5, the variance of the four principal extracted components were greater than 0.6 and they cumulatively explained a 61.64% total variance. Table 6 shows the rotated component matrix in which absolute values less than 0.5 were suppressed.

After examining the effect of each component on employee participation, the four principal components were renamed respectively as "Objective 1: Activity in forum"; "Objective 2: Statistic of knowledge system"; "Objective 3: Participation of KM activity"; and "Objective 4: Number of documents". The four principal components are the renamed factors of four objectives shown in Table 7.

Objective 1 was designated "Activity in forum" because its factors included records of submissions, replies, additional answers, and submitted topics with a final solution in forum. Moreover, submitting and replying in the SOS system was similar to activity in a forum. The activity in forum was an integrated workflow with personalized alerts and on-line information sharing (Chang, Li 2007) .

Objective 2 was named "Statistic of knowledge system", which focused on the usage in the system and is important for knowledge reinforcement (Kreng, Tsai 2003; Chang, Li 2007). All records tracked employee participation, which included the records of uploading and sharing record documents, login frequency, reading on-line documents, working and non-working time, pages printing, and category records.

Objective 3 was labeled "Participation of KM activity", which helps employees to articulate, capture, and share experts' experiences (Butler, Murphy 2007). All records represented real activity in the KMS, including uploading and sharing personal documents, publications' recommend times and scores, regular activity and host records in the knowledge community, and training classes.

Objective 4, "Number of documents", was an important control point in KM evaluation (Chang, Li 2007). For instance, these records held patent applications, contacts of publicly recognized managers, published reports, and books searched or borrowed.

4.2. Final survey

In the final survey, this research sent 104 questionnaires, to which there were 54 responses. The effective response

Table 3. Measurement factors used by engineering consulting firms

No.	Description of the factors	A	B	C	Related literature
1	Search records for documents.		○	○	Chua (2004)
2	Records on knowledge community participation.		○		McDermott (2000); Ford, Chan (2003); Du Plessis (2008)
3	Records on documents published in local publications.			○	Chua (2004)
4	Submitted records of topics or issues in discussion forum.	○	○	○	McDermott (2000); Ford, Chan (2003)
5	The records of KM contest reputation and related KM competition games.			○	McDermott (2000); Du Plessis (2008)
6	Records on popular books recommendation.		○		Lin, Kuo (2007); Du Plessis (2008)
7	Login records.	○	○	○	Chua (2004)
8	Additional responses recorded in discussion forums.	○	○	○	McDermott (2000); Ford, Chan (2003); Lin, Tseng (2005)
9	The number of times a publication is recommended, and its user rating.	○			Du Plessis (2008)
10	Uploaded records for quoted references.		○		Choi, Lee (2003); Lin, Kuo (2007); Tseng (2008)
11	The number of times records within attending and training classes.		○		Du Plessis (2008)
12	Replies in discussion forum.		○		McDermott (2000); Lin, Kuo (2007); Du Plessis (2008)
13	Records of regular activity in knowledge community.			○	McDermott (2000); Du Plessis (2008)
14	Host activities recorded in knowledge community.		○		McDermott (2000); Lin, Kuo (2007); Du Plessis (2008)
15	Patent applications accepted for each employee.			○	
16	The records of internal reports published by the company.		○		Chua (2004); Lin, Kuo (2007); Du Plessis (2008)
17	Categories of on-line reading.	○	○		
18	The record of contact experts in company.			○	Choi, Lee (2003); Lin, Kuo (2007); Du Plessis (2008)
19	Submissions to SOS (emergency problem) system.		○	○	McDermott (2000); Ford, Chan (2003); Du Plessis (2008)
20	Participation records in Knowledge Management Contest.			○	Lin, Kuo (2007); Du Plessis (2008)
21	Personal documents uploaded and shared.		○	○	Choi, Lee (2003); Du Plessis (2008); Tseng (2008)
22	The records being key presenter and the lecture in training course in company.		○		McDermott (2000); Lin, Kuo (2007); Du Plessis (2008)
23	Books borrowed.		○		Chua (2004)
24	Submitted topics with a final solution in the forum.	○	○	○	Choi, Lee (2003); Lin, Kuo (2007); Du Plessis (2008)
25	The participation records of sharing experience from retired employees.		○	○	Lin, Kuo (2007); Du Plessis (2008); Tseng (2008)
26	Members in knowledge community.			○	McDermott (2000); Kreng, Tsai (2003)
27	Number of read documents.		○	○	Chua (2004)
28	Replies to discussion forum.		○		McDermott (2000); Lin, Kuo (2007); Du Plessis (2008)
29	Pages printed.	○	○		Chua (2004)
30	Public recognition of managers.			○	Tseng (2008b); Du Plessis (2008)
31	Pages viewed in publications.	○			Chua (2004)
32	Records of on-line documents read.	○	○		Chua (2004)

Continued of Table 3

No.	Description of the factors	A	B	C	Related literature
33	Pages viewed records of each organization.	○			Chua (2004)
34	The system used records in working and non-working time.		○		Chua (2004)
35	Records of on-line documents.	○	○		Chua (2004)
36	Frequency of logins to KMS.			○	Chua (2004)
37	Replies recorded in SOS (emergency problem) system.		○	○	McDermott (2000); Ford, Chan (2003); Lin, Kuo (2007)

Table 4. KMO and Bartlett's test of path analysis

Kaiser–Meyer–Olkin measure of sampling adequacy	Bartlett's test of sphericity		
	Approximate chi square	DOF[a]	Significance
0.532	874.472	496	0.000

[a]DOF = degree of freedom.

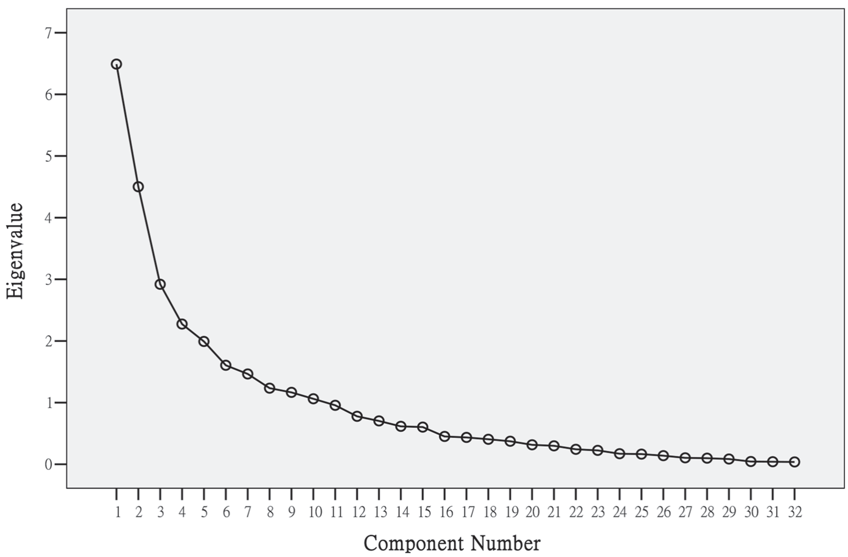

Fig. 1. Scree plot for factor analysis

rate was 51.92%. The final survey questionnaire designed for this research consisted of two parts, including (1) the 32 sub-factors of four objective factors for employee participation in the KMS, and (2) the cause-effect relationship among four objective factors.

Table 8 illustrates a reliability analysis of the various objective factors and sub-factors, and shows that the reliability of the objective factors is higher than 0.7, that of the sub factors is higher than 0.6, and the overall reliability of the scale is over 0.8. The results show a high consistency and reliability of the final survey.

In order to understand the relationship between four objective factors, this study used a Pearson correlation analysis (Table 9). A higher positive correlation was found in the objective factors of "Activity in forum" versus "Participation of KM activity"; "Activity in forum" versus "Number of documents"; and "Participation of KM activity" versus "Number of documents", whose significant values were less than 0.01, and had correlation values of 0.603**, 0.447**, and 0.689**, respectively. The positive correlation in the objective factors of "Activity in forum" versus "Statistic of knowledge system", and "Statistic of knowledge system" versus "Number of documents", whose significant values were less than 0.05, had correlation values of 0.295* and 0.285*, respectively. An insignificant value was "Statistic of knowledge system" versus "Participation of KM activity", which had a correlation value of 0.028.

Table 5. The variance explained by extracted major components

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	11.185	32.896	32.896	11.185	32.896	32.896
2	4.456	13.106	46.002	4.456	13.106	46.002
3	2.902	8.537	54.539	2.902	8.537	54.539
4	2.417	7.108	61.646	2.417	7.108	61.646

Table 6. Rotated component matrix for measurement factors of employee participation in KMS

	Component									
	1	2	3	4	5	6	7	8	9	10
No. 28	.828	–	–	–	–	–	–	–	–	–
No. 8	.793	–	–	–	–	–	–	–	–	–
No. 37	.658	–	–	–	–	–	–	–	–	–
No. 24	.569	–	–	–	–	–	–	–	–	–
No. 25	.564	–	–	–	–	–	–	–	–	–
No. 19	.548	–	–	–	–	–	–	–	–	–
No. 10	.501	–	–	–	–	–	–	–	–	–
No. 4	.479	–	–	–	–	–	–	–	–	–
No. 36	–	.799	–	–	–	–	–	–	–	–
No. 20	–	.788	–	–	–	–	–	–	–	–
No. 7	–	.627	–	–	–	–	–	–	–	–
No. 32	–	.622	–	–	–	–	–	–	–	–
No. 34	–	–	.878	–	–	–	–	–	–	–
No. 35	–	–	.765	–	–	–	–	–	–	–
No. 29	–	–	.612	–	–	–	–	–	–	–
No. 17	–	–	.533	–	–	–	–	–	–	–
No. 21	–	–	–	.779	–	–	–	–	–	–
No. 9	–	–	–	.756	–	–	–	–	–	–
No. 13	–	–	–	.707	–	–	–	–	–	–
No. 33	–	–	–	–	.905	–	–	–	–	–
No. 31	–	–	–	–	.832	–	–	–	–	–
No. 27	–	–	–	–	.533	–	–	–	–	–
No. 14	–	–	–	–	–	.851	–	–	–	–
No. 22	–	–	–	–	–	.802	–	–	–	–
No. 15	–	–	–	–	–	–	.808	–	–	–
No. 30	–	–	–	–	–	–	.721	–	–	–
No. 16	–	–	–	–	–	–	.535	–	–	–
No. 1	–	–	–	–	–	–	–	.762	–	–
No. 23	–	–	–	–	–	–	–	.696	–	–
No. 18	–	–	–	–	–	–	–	.416	–	–
No. 2	–	–	–	–	–	–	–	–	.809	–
No. 26	–	–	–	–	–	–	–	–	–	.626

The framework in the KMS processes data into information and knowledge (Davenport, Prusak 2000). Therefore, this research assumes that employee participation in the KMS also requires access to both the data and knowledge (Davenport *et al.* 1996; Davenport, Prusak 2000; Bhatt 2001; Sambamurthy, Subramani 2005; Tseng 2008a). The results in the final survey were the analysis of the four objective factors; their relationships in knowledge management are shown in Figure 2.

The objective factor, "Number of documents", which collected records about the number of documents

Table 7. The Cronbach's Alpha of extracted principal components

Objective No.	The number of factors								Cronbach Alpha
1	No. 28	No. 8	No. 37	No. 24	No. 25	No. 19	No. 10	No. 4	0.806
2	No. 36	No. 20	No. 7	No. 32	No. 34	No. 35	No. 29	No. 17	0.827
3	No. 21	No. 9	No. 13	No. 33	No. 31	No. 27	No. 14	No. 22	0.723
4	No. 15	No. 30	No. 16	No. 1	No. 23	No. 18	No. 2	No. 26	0.676

Table 8. Reliability and average score of various factors in the scale

Objective Factors/ Sub Factors	Cronbach's Alpha	Mean	S.D.
Activity in the forum	*0.753*	*32.22*	*2.96*
No. 4 Submitted records of topics or issues in discussion forum.	0.688	3.78	0.54
No. 28 Replies to discussion forum.	0.721	3.94	0.53
No. 8 Additional responses recorded in discussion forums.	0.716	3.89	0.57
No. 19 Submissions to SOS (emergency problem) system.	0.735	4.28	0.74
No. 37 Replies recorded in SOS (emergency problem) system.	0.742	4.44	0.50
No. 24 Submitted topics with a final solution in forum.	0.769	4.28	0.66
No. 10 Uploaded records for quoted references.	0.707	3.56	0.60
No. 25 The participation records of sharing experience from retired employees.	0.734	4.06	0.71
Statistic of knowledge system	*0.854*	*23.17*	*4.04*
No. 35 Number of on-line documents.	0.830	2.89	0.66
No. 32 Records of on-line documents read.	0.840	3.00	0.75
No. 17 Categories of on-line reading.	0.807	2.94	0.79
No. 29 Printed pages.	0.812	2.50	0.69
No. 7 Login records.	0.834	2.72	0.74
No. 36 Frequency of logins to KMS.	0.840	2.78	0.72
No. 34 The system use records in working and non-working time.	0.849	3.17	0.84
No. 20 Participation records in Knowledge Management Contest.	0.869	3.17	0.51
Participation of KM activity	*0.811*	*30.51*	*3.70*
No. 14 Host activities recorded in knowledge community.	0.777	4.22	0.72
No. 21 Personal documents uploaded and shared.	0.759	4.06	0.79
No. 22 The records being key presenter and the lecture in training course in company.	0.759	4.17	0.84
No. 13 Records of regular activity in knowledge community.	0.831	4.00	0.58
No. 9 The number of times a publication is recommended, and its user rating.	0.737	3.83	0.91
No. 31 Pages viewed for each publication.	0.769	3.50	0.69
No. 27 Number of read documents.	0.854	3.17	0.38
No. 33 Pages viewed for each organization.	0.779	3.56	0.60
Number of documents	*0.788*	*27.67*	*3.34*
No. 2 Records on knowledge community participation.	0.728	3.89	0.66
No. 1 Search records for documents.	0.774	3.06	0.53
No. 23 Books borrowed.	0.803	2.83	0.61
No. 18 The record of contact experts in company.	0.751	3.72	0.56
No. 26 Members in knowledge community.	0.826	3.17	0.38
No. 16 The records of internal reports published by company.	0.743	3.89	0.46
No. 30 Public recognition of managers.	0.737	3.67	0.75
No. 15 Patent applications accepted for each employee.	0.702	3.44	1.08

Table 9. The correlation matrix of objective factors

	Activity in forum	Statistic of knowledge system	Participation of KM activity	Number of documents
Activity in forum	1			
Statistic of knowledge system	.295*	1		
Participation of KM activity	.603**	.028	1	
Number of documents	.447**	.285*	.689**	1

Note: *P < 0.05; **p < 0.01.

from consulting firms in the KMS, not only translated raw data and information, but was also developed by referring to the results of other objective factors such as "Activity in forum", "Statistic of knowledge system", and "Participation of KM activity".

The participation of employees in the use of the KMS is an implicit behavior, and is thus not easy to quantify. Through the study of factors, we found four major quantifiable components, which are the Number of documents, Activity in forum, Statistic of knowledge system, and Participation in KM activity. From the interviews and the results of this study, these four components matched the transformation framework from data, to information, to knowledge. In future, this framework may help engineering consulting firms to understand if employees participate in the implementation of KMS. Furthermore, the study reveals the indirect beneficial effect of KMS on existing procedures.

The other objective factors, "Activity in forum", "Statistic of knowledge system", and "Participation of KM activity", were found to be fundamental factors in employee participation in KMS implementation. "Statistic of knowledge system" and "Participation of KM activity" represent tacit knowledge. Tacit knowledge translates into explicit knowledge in the "Activity in forum". Hence, these factors both directly and indirectly translate tacit knowledge into explicit knowledge. The theoretical model of these four objective factors is shown in Figure 3.

4.3. Path analysis and discussion

In statistics, path analysis is used to describe the directed dependencies between a set of variables. This includes using models equivalent to any form of multiple regression analysis and factor analysis. In order to calculate validly the relationship between any two components in the diagram, scholars proposed a simple set of path tracing rules (Wright 1934) for calculating the correlation between two variables. The rules for path tracing are: the investigator traces backward up an arrow and then forward along the next, or forwards from one variable to the other, but never forward and then back; the investigator can then pass through each variable only once in a given chain of paths.

Because correlation analysis does not verify a cause-effect relationship (Huang, Hsueh 2007; Cheng *et al.* 2010), we applied the path analysis method for discovering a cause-effect relationship for the four principal factors. The path analysis method was a simplified type of structural equation modeling that used a series of regression analyses for verifying the theoretical model (Huang, Hsueh 2007; Lin, Kuo 2007). This research separated the path analysis into two equations. The first equation analyzed the objective factors for

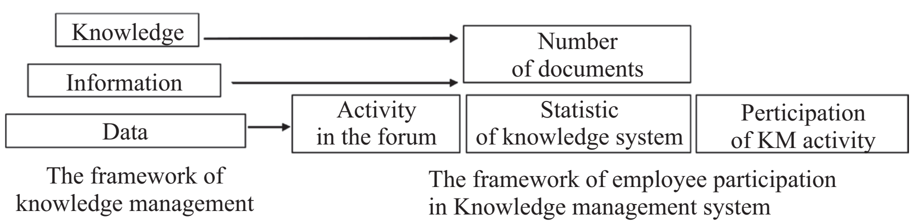

Fig. 2. The framework of Knowledge Management and Employee Participation in KMS

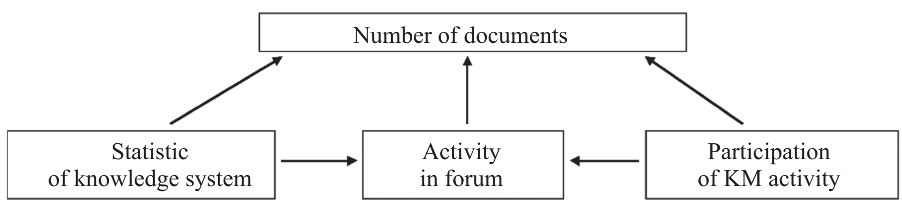

Fig. 3. The theoretical model of Employee Participation in KMS

the number of documents, and the second equation focused on the objective factor in the activity in forum. These two equations were expressed in further regression equations:

$$\text{First Equation: } Y_1 = b_1X_1 + b_2X_2 + b_3X_3 + \varepsilon_1; \quad (1)$$

$$\text{Second Equation: } Y_2 = b_4X_1 + b_5X_3 + \varepsilon_2, \quad (2)$$

where: Y_1 – number of documents; Y_2 – activity in forum; X_1 – statistic of knowledge system; X_2 – activity in forum; X_3 – participation of KM activity; ε_n – n = 1~2, error term.

The cause-effect relationship and path coefficients within the path analysis are shown in Figure 4 (Wright 1921, 1934). The results in the first equation indicated three paths to the number of documents, including the statistic of knowledge system, the activity in forum, and the participation of KM activity. The paths of the statistic of knowledge system and the participation of KM activity were direct and significantly influenced the number of documents; their path coefficients were 0.286** and 0.727**. The second equation indicated two paths to the activity in forum factor, which including statistic of knowledge system and the participation of KM activity. These two paths were both direct and had a significant influence on the activity in forum, and their path coefficients were 0.278** and 0.595**. These two equations proved that the statistic of knowledge system and the participation of KM activity both have two direct cause-effect relationships with the number of documents and the activity in forum.

The significant relations presented above are consistent with most of the foregoing conditions in this research. However, the objectives of "Activity in forum" and "Number of documents" do not have a significant cause-effect relationship. All three case studies indicated that tacit knowledge and explicit knowledge were not only hidden in the discussion forum, but were also difficult to distinguish from one another. Because the factors under the objectives of "Activity in forum" included both explicit and tacit knowledge, the results of the analysis are not a significant cause-effect relation. Both tacit and explicit knowledge were compared with the principal factor of "Number of documents" and were not found to indicate a cause-effect relationship in this research.

The content inside "Activity in forum" includes known and unknown topics, wrong and correct replies, and positive and negative discussion in which complicated tacit knowledge can be converted into explicit knowledge. Future research might discover how to distinguish tacit and explicit knowledge embedded within the activity in forum.

Conclusions

There have been numerous studies dealing with the interpretation of tacit and explicit knowledge in the field of KM. This study differs from the routine by proposing a framework within which measurement factors correlate with one another to make the best use of KMS.

The results of the questionnaire to illustrate tacit and explicit knowledge are relatively subjective to different requirements. For example, the regular rules of project planning and design specification are explicit knowledge to senior engineers, but tacit knowledge, hidden in every ongoing project, to junior engineers. Another example, solving different project problems is explicit knowledge to senior staff, but to junior engineers, it takes actual experience or project knowledge translated by senior engineers. The tacit knowledge hidden in documents can be shared structurally in KMS. As a result, more discussion in this study goes around the engineering consulting firm's operation of measurement factors to examine the degree to which the employee participation in each feature of the KMS is in use.

This research summarizes the literature and case studies for building a measurement system and uses a quantifiable survey method in independent-samples T-tests, factor analysis, relevant reliability and validity tests, and path analysis for identifying employee participation in KMS within engineering consulting firms. Four objectives were verified and termed as "Activity in forum", "Statistic of knowledge system", "Participation of KM activity", and "Number of documents". The result of path analysis indicated four significant paths, including Statistic of knowledge system → Number of documents; Participation of KM activity → Number of documents; Statistic of knowledge system → Activity in forum; and Participation of KM activity → Activity in forum.

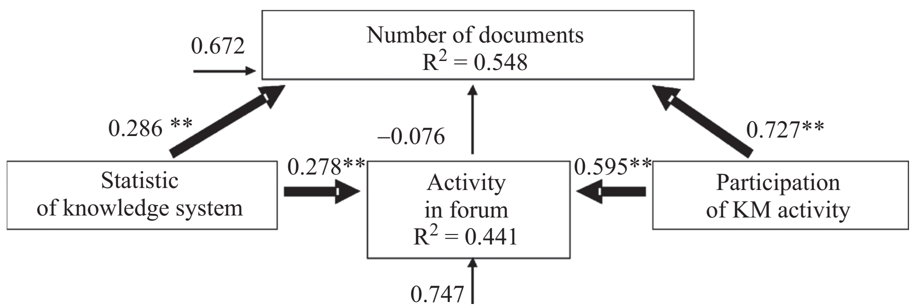

Fig. 4. The path analysis diagram, *P < 0.05, **p < 0.01

KMS have been widely used in engineering consulting firms but managers are sometimes not able to understand the results and performance of the implemented KMS. Therefore, this study can help managers to understand systematically the different levels of employee participation reflected in our KMS implementation results. This study transformed 37 measurement factors into four principal components to indirectly illustrate the results and performance of KMS. We used the cause-effect relationship analysis to show that the components in KMS, "Statistic of knowledge system", "Activity in forum", and "Participation of KM activity", are quantitative indicators that reflect whether the KMS is useful. All indicators will be presented to "Number of documents" in the end.

Managers would be concerned with employee participation in the KMS implementation process, especially when the number of documents increases significantly. However, managerial focus is usually on profit post-KMS implementation, not whilst the system is ongoing. If the number of documents stays the same, then it is possible that the activities separate from the existing operation procedures in KMS. If the number of documents continues to increase, it could verify that KMS activities have indeed been integrated with existing operation procedures. This can be considered as a successfully implemented KMS.

The study found that best practice is to increase the number of documents in the KMS post-implementation, highlighting the need to create and increase documents. For instance, when experts and senior engineers face problems, the memorandum of understanding documents (MOU) should be produced. The contents of the MOU documents includes information such as the name of the expert, what the problem is, when it happens, why the problem occurs, and how it was solved. The documents of these discussions need to be retained in the KMS. Another example is the list of experts and the reasons why an original procedure is modified into a new procedure. Before implementing the KMS, these documents are held by different employees in different data formats at different places. These documents need to be unified, modified, and stored in the KMS, for the purpose of solving similar problems in the future.

There are two contributions from this research: (1) the engineering consulting firms that are planning to implement or that have already implemented a KMS could reference the results of this research for measurement factors for their employee participation; and (2) the cause-effect relationship could remind managers to rediscover the fundamental factors. If an engineering consulting firm is planning to implement a KMS, the proposed measurement factors and the results can be used as a tool before bringing in resources for KMS support. The designer of the KMS will be able to consider what information needs to be documented. Measuring the degree of employee participation in the consulting firm helps to reduce the cost of post-customization. In addition, the manager can determine whether the implementation of the KMS changes the operating procedures within the company by the statistical results from these factors. These statistical results can be used as indicators for KMS improvement.

Future research could use the measurement factors in this paper to compare different factors between general contractors and engineering consulting firms. In addition to employee participation, employee satisfaction with a KMS is another significant topic in the construction industry. Future research could focus on a feasibility study to evaluate and analyze the potential benefits associated with implementing a KMS as well as employee satisfaction to investigate barriers to the planning and implementation of KMS.

References

Alavi, M.; Leidner, D. E. 2001. Review: knowledge management and knowledge management systems: conceptual foundations and research issues, *MIS Quarterly* 25(1): 107–136. http://dx.doi.org/10.2307/3250961

Bhatt, G. D. 2001. Knowledge management in organizations: examining the interaction between technologies, techniques, and people, *Journal of Knowledge Management* 5(1): 68–75. http://dx.doi.org/10.1108/13673270110384419

Bowman, B. J. 2002. Building knowledge management systems, *Information Systems Management* 19(3): 32–40. http://dx.doi.org/10.1201/1078/43201.19.3.20020601/37168.5

Brown, A.; Adams, J.; Amjad, A. 2007. The relationship between human capital and time performance in project management: a path analysis, *International Journal of Project Management* 25(1): 77–89. http://dx.doi.org/10.1016/j.ijproman.2006.07.011

Butler, T.; Murphy, C. 2007. Understanding the design of information technologies for knowledge management in organizations: a pragmatic perspective, *Information Systems Journal* 17(2): 143–163. http://dx.doi.org/10.1111/j.1365-2575.2007.00237.x

Carrillo, P.; Chinowsky, P. 2006. Exploiting knowledge management: the engineering and construction perspective, *Journal of Management in Engineering* 22(1): 2–10. http://dx.doi.org/10.1061//(asce)0742-597x(2006)22:1(2)

Chang, W. C.; Li, S. T. 2007. Fostering knowledge management deployment in R&D workspaces: a five-stage approach, *R&D Management* 37(5): 479–493. http://dx.doi.org/10.1111/j.1467-9310.2007.00484.x

Cheng, C. W.; Lin, C. C.; Leu, S. S. 2010. Use of association rules to explore cause–effect relationships in occupational accidents in the Taiwan construction industry, *Safety Science* 48(4): 436–444. http://dx.doi.org/10.1016/j.ssci.2009.12.005

Choi, B.; Lee, H. 2003. An empirical investigation of KM styles and their effect on corporate performance, *Information & Management* 40(5): 403–417. http://dx.doi.org/10.1016/S0378-7206(02)00060-5

Davenport, T. H.; Jarvenpaa, S. L.; Beers, M. C. 1996. Improving knowledge work processes, *Sloan Management Review* 37: 53–66.

Davenport, T. H.; Prusak, L. 2000. *Working knowledge: how organizations manage what they know*. Harvard: Business Review Press, 123–143.

Demian, P.; Fruchter, R. 2006. An ethnographic study of design knowledge reuse in the architecture, engineering,

and construction industry, *Research in Engineering Design* 16(4): 184–195.
http://dx.doi.org/10.1007/s00163-006-0010-x

Ding, Y.; Zhou, H. W.; Deng, S. Y.; Comm, E. B. M. O. 2011. Professional service firm's business development: a case study on Chinese engineering consulting firms, in *The 2nd International Conference on Engineering and Business Management*, 22–24 March 2011, Wuhan, China. No. 80982.

Du Plessis, M. 2008. What bars organizations from managing knowledge successfully?, *International Journal of Information Management* 28(4): 285–292.

Goh, B. 2006. Creating intelligent enterprises in the Singapore construction industry to support a knowledge economy, *Building and Environment* 41(3): 367–379.
http://dx.doi.org/10.1016/j.buildenv.2005.01.021

Group, G. 1999. Knowledge management: understanding the core value and science, *Gartner Group Business Technology Journal* 33: 82–92.

Henson, R. K. 2001. Understanding internal consistency reliability estimates: a conceptual primer on coefficient alpha, *Measurement and Evaluation in Counseling and Development* 34(3): 177–189.

Huang, C. F.; Hsueh, S. L. 2007. A study on the relationship between intellectual capital and business performance in the engineering consulting industry: a path analysis, *Journal of Civil Engineering and Management* 13(4): 265–271.

Kreng, V. B.; Tsai, C. M. 2003. The construct and application of knowledge diffusion model, *Expert Systems with Applications* 25(2): 177–186.
http://dx.doi.org/10.1016/S0957-4174(03)00045-9

Lee, S. M.; Hong, S. 2002. An enterprise-wide knowledge management systems infrastructure, *Industrial Management & Data Systems* 102(1): 17–25.
http://dx.doi.org/10.1108/02635570210414622

Lin, C.; Tseng, S. M. 2005. Bridging the implementation gaps in the knowledge management systems for enhancing corporate performance, *Expert Systems with Applications* 29(1): 163–173.
http://dx.doi.org/10.1016/j.eswa.2005.01.015

Lin, C. Y.; Kuo, T. H. 2007. The mediate effect of learning and knowledge on organizational performance, *Industrial Management & Data Systems* 107(7): 1066–1083.
http://dx.doi.org/10.1108/02635570710816748

Lin, Y. C.; Lee, H. Y. 2012. Developing project communities of practice-based knowledge management systems in construction, *Automation in Construction* 22: 422–432.
http://dx.doi.org/10.1016/j.autcon.2011.10.004

Lin, Y. C.; Wang, L. C.; Tserng, H. P. 2006. Enhancing knowledge exchange through web map-based knowledge management systems in construction: lessons learned in Taiwan, *Automation in Construction* 15(6): 693–705.
http://dx.doi.org/10.1016/j.autcon.2005.09.006

Ling, F. Y. Y.; Gui, Y. 2009. Strengths, weaknesses, opportunities, and threats: case study of consulting firms in Shenzhen, China, *Journal of Construction Engineering and Management* ASCE 135(7): 628–636.
http://dx.doi.org/10.1061/(asce)co.1943-7862.0000003

Mortazavi, S. M. H. 2010. *Consulting engineering firms as learning organization*. Academic Conferences Ltd.

Nonaka, I.; Takeuchi, H. 2007. The knowledge-creating company, *Harvard Business Review* 85(7/8): 162.

O'Dell, C.; Grayson, C. J. 1998. If only we knew what we know: identification and transfer of internal best practices, *California Management Review* 40(3): 154–174.
http://dx.doi.org/10.2307/41165948

Peterson, R. A. 1994. A meta-analysis of Cronbach's coefficient alpha, *Journal of Consumer Research* 21(2): 381–391.
http://dx.doi.org/10.1086/209405

Pett, M. A.; Lackey, N. R.; Sullivan, J. J. 2003. *Making sense of factor analysis: the use of factor analysis for instrument development in health care research*. California: SAGE Publications, Inc. 348 p.

Quaddus, M.; Xu, J. 2005. Adoption and diffusion of Knowledge management systems: field studies of factors and variables, *Knowledge-Based Systems* 18(2): 107–115.
http://dx.doi.org/10.1016/j.knosys.2004.11.001

Sambamurthy, V.; Subramani, M. 2005. Special issue on information technologies and knowledge management, *MIS Quarterly* 29(2): 193–195.

Teh, P. L.; Yong, C. C. 2011. Knowledge sharing in is personnel: organizational behavior's perspective, *Journal of Computer Information Systems* 51(4): 11–21.

Tseng, S. M. 2008a. The effects of information technology on Knowledge management systems, *Expert Systems with Applications* 35(1): 150–160.
http://dx.doi.org/10.1016/j.eswa.2007.06.011

Tseng, S. M. 2008b. Knowledge management systems performance measure index, *Expert Systems with Applications* 34(1): 734–745.
http://dx.doi.org/10.1016/j.eswa.2006.10.008

Tserng, H. P.; Lin, Y. C. 2004. Developing an activity-based knowledge management systems for contractors, *Automation in Construction* 13(6): 781–802.
http://dx.doi.org/10.1016/j.autcon.2004.05.003

Tserng, H. P.; Yin, S. Y. L.; Lee, M. H. 2010. The use of knowledge map model in construction industry, *Journal of Civil Engineering and Management* 16(3): 332–344.
http://dx.doi.org/10.3846/jcem.2010.38

Tuzovsky, A. F.; Yampolsky, V. Z. 2003. The system approach to Knowledge management systems designing and development, in *Proc. of KORUS 2003, The 7th Korea-Russia International Symposium on Science and Technology*, 6 July 2003, Ulsan, South Korea, 2: 319–323.

Wright, S. 1921. Correlation and causation, *Journal of Agricultural Research* 20(7): 557–585.

Wright, S. 1934. The method of path coefficients, *The Annals of Mathematical Statistics* 5(3): 161–215.
http://dx.doi.org/10.1214/aoms/1177732676

Wu, J. W.; Tseng, J. C. R.; Yu, W. D.; Yang, J. B.; Lee, S. M.; Tsai, W. N. 2012. An integrated proactive knowledge management model for enhancing engineering services, *Automation in Construction* 24: 81–88.
http://dx.doi.org/10.1016/j.autcon.2012.02.006

Yang, L. R.; Chen, J. H.; Wang, H. W. 2012. Assessing impacts of information technology on project success through knowledge management practice, *Automation in Construction* 22: 182–191.
http://dx.doi.org/10.1016/j.autcon.2011.06.016

Yin, S. Y. L.; Tserng, H. P.; Tsai, M. D. 2008. A model of integrating the cycle of construction knowledge flows: lessons learned in Taiwan, *Automation in Construction* 17(5): 536–549.
http://dx.doi.org/10.1016/j.autcon.2007.10.002

Yu, W. D.; Yang, J. B.; Tseng, J. C. R.; Liu, S. J.; Chang, P. L. 2009. Enhancing engineering services with integrated proactive knowledge management model, in *International Symposium on Advancement of Construction Management and Real Estate, CRIOCM 2009*, 29–31 October 2009, Nanjing, China, 2409–2416.

Yu, Z.; Haghighat, F.; Fung, B. C. M.; Zhou, L. 2012. A novel methodology for knowledge discovery through mining associations between building operational data, *Energy and Buildings* 47: 430–440.
http://dx.doi.org/10.1016/j.enbuild.2011.12.018

Yuan, J. F.; Skibniewski, M. J.; Li, Q.; Shan, J. 2010. The driving factors of China's public-private partnership projects in Metropolitan transportation systems: public sector's viewpoint, *Journal of Civil Engineering and Management* 16(1): 5–18.
http://dx.doi.org/10.3846/jcem.2010.01

Zhang, X. Q. 2006. Factor analysis of public clients' best-value objective in public-privately partnered infrastructure projects, *Journal of Construction Engineering and Management* ASCE 132(9): 956–965.
http://dx.doi.org/10.1061/(asce)0733-9364(2006)132:9(956)

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