Is the Knowledge Management System Truly Cost Effective? Case Study of KM-Enabled Engineering Problem Solving

Wen-Der Yu¹; Ting-Chun Lin²; Shen-Jung Liu³; and Pei-Lun Chang⁴

Abstract: Managers of construction organizations have long been faced with the essential question of whether the knowledge management system (KMS) is truly cost effective. Very few empirical studies have been conducted to measure the effective benefits of implementing knowledge management initiatives. A lack of quantitative measurement models, the difficulty of differentiating knowledge management (KM) from non-KM activities, the difficulty of evaluating the resultant KM activity values, and an unwillingness of organizations to reveal insights (aimed at shielding these insights from their competitors) are critical reasons for their absence from empirical reports. This paper reveals a five-year comprehensive benefit survey on the implementation of a specialized KMS, KM-enabled problem solver, at a major engineering consulting firm. In total, 868 emergency problem-solving scenarios recorded in the KMS were analyzed. Three that were most concerned with benefit indexes (time, cost, and staff hours) selected by the KM managers were measured. Results showed timeliness to be the most remarkable tangible benefit. Both staff hours and cost benefits were negative. Qualitative benefits were identified and addressed through focus group meetings with the KM managers. The KM approach was not suited to solving all types of engineering problems. Strategies should be taken to facilitate engineering problem solving, including development of a more proactive approach. DOI: 10.1061/(ASCE)CO.1943-7862.0000604. © 2013 American Society of Civil Engineers.

Case Study

Introduction

Construction organizations, such as design and engineering consulting and construction firms, have been increasingly adopting knowledge management (KM) approaches as a useful means of exploiting and utilizing knowledge assets (Mezher et al. 2005; Carrillo and Chinowsky 2006; Lin et al. 2006; Dave and Koskela 2009; Yu et al. 2010). Communities of practice (CoPs) and knowledge bases (KBs) are two of the most popular forms of knowledge management system (KMS) implementations in a construction organization. A CoP can be defined as a group of people informally bound together by shared expertise and passion for a joint enterprise (Yu et al. 2009), in which communities develop their practice through a variety of activities, such as problem solving, requests for information, seeking experience, reusing assets, coordination and synergy, discussing developments, documentation projects, visits, mapping knowledge and identifying gaps. KBs are repositories of the knowledge documentations that record the knowledge and experiences accumulated by the organization on special subjects. Solving problems encountered in their activities is the most common KM activity of the staff in a construction organization.

Despite its wide adoption, a fundamental question faces managers of construction organizations. Does a KMS justify its cost and, if so, how beneficial is it? Such a question is difficult to answer in the absence of convincing quantitative analysis results. After a thorough survey of relevant literature, the authors found few reports that address a quantitative benefit analysis of KMS implementation. Several reasons for such a result may include: (1) the difficulty of benefit measurement, (2) the difficulty of differentiating (KM) and non-KM activities, (3) the difficulty of evaluating the resultant KM activity values, and (4) the unwillingness of organizations to reveal insights, aimed at shielding such insights from their competitors. Among these four reasons, corporate unwillingness to reveal data is probably the most important reason behind the fact that KMS performance is rarely reported. Whereas some attempts to establish quantitative performance models for KM implementations have been made (Swaak et al. 2000; Bassion et al. 2005; Del-Rey-Chamorro et al. 2003; Yu et al. 2009), most focused on (indicator-based) indirect measures rather than direct benefits (e.g., time savings, cost effectiveness and staff hour reductions), which are of most interest to the top managers of the firm. Without convincing direct measures of KMS benefits, exploring KM implementation effectiveness further has been difficult, as has setting optimal budgets and estimating expected returns. Such causes have resulted in KMS black box implementations. In fact, many organizations that have implemented KMS have not measured their benefits.

This paper reveals a five-year comprehensive benefit survey on the implementation of a specialized KMS, KM-enabled.
construction problem solver (KM-CPS), at a major engineering consulting firm of Taiwan. In total, 868 emergency problem-solving cases recorded in the KMS were collected and analyzed. The three most interesting benefit indices (time, cost, and staff hours) were selected by the CoP managers through focus-group meetings. The quantitative measurement models for the selected benefit indices are defined. A web-based questionnaire system was developed to collect the required information for quantitative benefit analysis from the participants of emergency problem-solving scenarios. Qualitative benefits were discovered through focus group meetings with the CoP and KM managers of the surveyed engineering consulting firm. Finally, findings from the case study are presented to provide managers of construction organizations with the authors’ insights of KMS implementation.

Case Study Background

The Firm

China Engineering Consultants, Inc. (CECI) is one of the top three leading engineering consulting firms in Taiwan. It was established with government funding in 1969 primarily to promote the country’s construction technology and facilitate national economic development. The firm currently employs approximately 1,800 full-time staff. Approximately one-half of the staff works at the firm’s Taipei headquarters, with the remainder working in branches around Taiwan and overseas. The firm maintains an overseas presence in southeast and south Asia, the Middle East, and mainland China. Headquarters, branches, and site offices are connected through an Intranet.

The firm encompasses five business groups, including the civil engineering, railway engineering, electrical and mechanical engineering, construction management, and business and administration groups. The annual revenue of the firm was approximately US$161.3 million in 2009. According to commercial disclosure information, the firm has completed over 1,700 projects during the past 40 years. The total value (construction budget) of all completed projects exceeds US$200 billion.

Type of Emergency Problems Encountered by CECI

The managers and engineers of CECI regularly confront emergency situations and crises in their daily employment (e.g., related to bidding decisions, design modifications, material selection, construction method determination, site condition variations, change orders, and dispute resolution). Some are attributable to the basic nature of the industry (e.g., the contracting system and fragmented organizations, which cause interface and communication barriers). The remaining situations and crises are caused by external factors (e.g., construction project and environment-related variability). Whatever the cause of emergencies, problem solving usually draws upon accumulated knowledge and experience.

There are essentially 11 categories of emergency problems that confront the case engineering consulting firm. These are the following:

- Request of client: such requests can be very diverse, e.g., an assessment of the impact of a change order, preparation for a request for proposal (RFP) that was not included in the contract, evaluation of a set of different alternatives, and so on,
- Reaction to an accident: accidents are omnipresent, are emergencies on construction sites, and problems in this category may include the rescue process and remediation method for the accident,
- Dispute resolution/contract execution: may relate to the interpretation of contract articles and should be determined within a time limit,
- Materials and equipment: primarily related to onsite activities or preconstruction planning,
- Safety/environment matters: may relate to requirements of governmental regulations,
- Request of engineering information: such requests are also diverse, and include the information of price of bid items or a design, construction method, and so on,
- Completion and transfer: problems that may happen when the project is completed and transferred to the client,
- SPEC and code: problems that are related to technical specifications or design codes,
- Problems with contractors/subcontractors: such problems are those raised by the contractors or subcontractors, and include schedule extension or claims of additional cost reimbursement,
- Internal process of the firm: related to the business/administration processes of CECI, and
- Other emergencies: all problems that do not belong to the previous categories.

Implementation of Knowledge Management System

To facilitate resolutions for the emergency problems encountered by the managers and engineers, the top management of CECI determined to adopt KMS. Implementation of KMS began in 2001. Unlike most other KMS implementations, CECI chose to develop its KMS completely in-house. The department of business and research made the initial KMS proposal. The department of information technology (IT) engineers subsequently joined the effort to handle technical problems encountered during system prototyping. The commercial software Microsoft SharePoint was adopted to develop the first version of KMS. Prototype development proceeded over the course of one year. Investments in hardware (i.e., both platforms and Microsoft SharePoint) and labor (programming, training, and maintenance) were, respectively, US$177,420 and US$612,900 (approximate values), for a total installation cost of approximately US$790,320.

The firm implemented the prototype KMS across the entire company after one year of project commencement. However, managers soon found that the difficulties involved with KMS development paled in comparison with the difficulties in creating an internal culture supportive of successful KMS operations. The firm established an initial 36 CoPs, which varied based on an enter-and-exit rule (i.e., continuous evaluation of CoPs determined whether each should be maintained or shut). During the study period, 36 CoPs were maintained in the KMS. The CoP manager handled CoP-related knowledge creation activities, and the company provided incentives to stimulate the establishment of a knowledge-sharing atmosphere. To date, the KMS has been operating for 8 years. The KMS has been modified significantly from its prototype version. One of the most significant modifications was the introduction of the KM-enabled construction problem solver (KM-CPS) for emergency problem solving in 2003.

The KM-CPS is a specialized CoP of the KMS, which provides a tentative forum for emergency problems encountered by the engineers and managers of the firm. Once the problem is posed as an emergency problem, it is posted in the KM-CPS board on the first page of the KMS for emergency discussions. Such an arrangement forces all users of the KMS to look at the posed problem, such that it generally receives attention and usually has a better chance of being solved. Problems posed on the KM-CPS board that receive
no response within one working day (i.e., 24 h since it was posted) will be automatically removed and transferred to ordinary CoPs. It subsequently becomes a regular topic for discussion in the relevant CoPs.

Method for Benefit Quantification

To measure the benefits that result from a KMS, a method for benefit quantification of the selected KM-CPS was developed. Prior to establishing such a quantitative model, the types of benefits to be quantified and the KM activities that add value to problem-solving processes must be identified.

Classes of Benefits Resulting from KM-CPS

Benefits resulting from a KM-CPS may be categorized into two types. The first are tangible benefits, which accrue to the organization from utilization of KM-CPS attributable to expedited problem solving (e.g., savings in terms of time, costs, and staff hours). The second are intangible benefits, such as enhanced firm reputation and knowledge assets, improved staff experience and knowledge, and increased organizational knowledge sharing. Five focus-group meetings with all of the CoP managers in the target engineering consulting firm were held from 2004–2006 and 2004–2008 to determine the type of benefits to be quantified. Meetings concluded that only the three previously noted tangible benefits (savings in time, costs, and staff hours) should be quantified in this research. Although intangible benefits were excluded because of the difficulty of establishing quantitative measurements at the beginning of the research, qualitative benefits were identified and addressed through focus group meetings with the CoP managers after data collection.

Identification of Value-Adding Activities

Adoption of a KM-CPS will result in reengineering of the internal business and operational processes of an organization. To identify value-adding KM activities, the traditional problem-solving process was compared with that of the KM-CPS to identify critical processes that generate benefits. Fig. 1 shows the problem-solving process in a traditional organizational problem-solving activity. In Fig. 1, a questioner first poses the problem to a sponsor (either a department or section head). The sponsor then determines a list of related departments and notifies them to participate in the problem-solving process. Typically, two to five departments will be involved for a regular problem. Managers from the notified departments will then select the proper engineers/managers to join the problem-solving taskforce. Subsequently, a cyclic problem-solving process starts with periodical or nonperiodical taskforce meetings, face-to-face interviews, and phone calls until a solution consensus is reached.

The problem-solving process was also analyzed for KM-CPS. Fig. 2 depicts the KM-CPS process for solving the same problem as noted in Fig. 1. In Fig. 2, a questioner poses the problem, which is then posted to the KM-CPS board (and relevant CoPs). Domain experts participate in KM-CPS board (or relevant CoP) discussions to suggest solutions or provide preliminary resolution ideas. Given that communications between questioner and responders are
transparent to all participants, no explanations are needed. Given that participants represent various specialties (even occasionally from outside the firm), the Medici effect expedites efficient knowledge conversions (Johansson 2002). Furthermore, given that all communications are conducted within the KM-CPS board and CoPs, no (or very limited) additional contacts (e.g., face-to-face interviews and phone calls) are typically required. When a satisfactory solution is researched, the questioner develops the final solution and the problem is solved.

By comparing the problem-solving processes of traditional and KM-CPS approaches, the authors found that the KM-CPS provides a better communication platform for participants because of the Medici enhancement effect. Furthermore, a KM-CPS also provides knowledge bases that expedite the combination conversion in Nonaka’s knowledge creation spiral (Nonaka 1994).

The quantitative benefit model was formulated based on observations made of the two different problem-solving processes. Quantitative equations were defined to measure the three tangible benefits delivered by traditional and KM-CPS problem-solving processes. The following subsection describes the benefit quantification model development in detail.

Quantification of Benefits

To quantify the benefits resulting from the KM-CPS system, the authors defined three quantitative benefit measures, as follows:

- Time-benefit: shortening of the time required to solve a problem with a KM-CPS compared with that required by the traditional process,
- Staff hour benefit: reduction in staff hours required to solve a problem with a KM-CPS compared with that required by the traditional process, and
- Cost benefit: savings in spent costs required to solve a problem with KM-CPS compared with that required by the traditional process.

Time benefit (TB) measures the ratio of time reduction for problem-solving achieved by KM-CPS relative to the traditional approach. TB is measured using Eq. (1), as follows:

\[
TB(\%) = \frac{ND_T - ND_S}{ND_T} \times 100\% \tag{1}
\]

where \(ND_T\) = number of working days required for the traditional problem-solving approach (estimated based on questioner experience); \(ND_S\) = number of working days required for problem solving with a KM-CPS (calculated based on the information recorded in the KM-CPS system and a questioner-completed survey); and \(TB\) = time saving (time benefit) ratio measured as a percentage (%)

Staff hour benefit (MHB) measures the ratio of staff hours required to solve a problem with the KM-CPS relative to the traditional approach. To calculate staff hour benefit, both staff hours spent in traditional and KM-CPS approaches must be recovered. Traditionally, the problem was solved using taskforce meetings, face-to-face interviews, and phone calls, with only related department staff attending meetings. The KM-CPS problem-solving process is quite different. A problem is posted to a CoP and all CoP members participate in discussions geared to find a solution. The following equation was employed to calculate the staff hour reduction ratio:

\[
MHB(\%) = \frac{TTT - STT}{TTT} \times 100\% \tag{2}
\]

where \(TTT\) = total staff hours spent in the traditional approach to solve the posed problem, estimated in Eq. (3); \(STT\) = total staff hours spent in a KM-CPS to resolve the same problem, estimated in Eq. (4); and \(MHB\) = staff hour benefit measured as a percentage (%)

For Eq. (2), the following equation was used to estimate the \(TTT\) (total staff hours spent for traditional problem solving):

\[
TTT = [(ND_T \times MC_T \times MP_T) + (MN_T \times MT_T \times MP_T)] + [(PA_T \times PF_T) + [(IA_T \times IF_T]] \tag{3}
\]

where \(ND_T\) and \(ND_S\) are as defined in Eq. (1); \(MC_T\) = questioner-estimated number of average daily (8 a.m. to 5 p.m.) staff hours spent by taskforce members; \(MP_T\) = total number of members participating in the taskforce on the posed problem; \(MN_T\) = questioner-estimated total number of taskforce meetings required for the posed problem; \(MT_T\) = questioner-estimated average number of working hours required for each taskforce meeting; \(PF_T\) = total number of phone calls placed by the questioner after the taskforce meetings; \(PA_T\) = questioner-estimated average number of working hours spent for each phone call; \(IF_T\) = total number of face-to-face interviews conducted by the questioner to relevant domain experts in addition to taskforce meetings and phone calls; and \(IA_T\) = questioner-estimated number of average working hours spent in each face-to-face interview.

Similarly, the \(STT\) (number of total staff hours spent for problem solving with a KM-CPS) was further calculated using the following equation:

\[
STT = \sum_{i=1}^{L} ORT_{Si} + \sum_{k=1}^{N} HRT_{Sk} + FAT_S \tag{4}
\]

where \(L\) = total number of responses in the KM-CPS board related to the posed problem within office working hours (i.e., 8 a.m. to 5 p.m.) recorded by the KMS; \(ORT_{Si}\) = number of working hours spent for the \(i\)th response estimated by the responder \(i\); \(N\) is the total number of responses in the KM-CPS board related to the posed problem after office working hours (i.e., before 8 a.m. or after 5 p.m.) recorded by the KMS; \(HRT_{Sk}\) = number of after-hours (i.e., before 8 a.m. or after 5 p.m.) spent for the \(k\)th response estimated by responder \(k\); and \(FAT_S\) = self-estimated time (in hours) required by the questioner to develop the final solution of the posed problem.

Cost benefit (CB) is always a central concern to top management, given that cost relates directly to financial performance and firm sustainability. Cost saving is a primary objective of KM-CPS investment. Should a KM-CPS fail to justify its cost, it would become much less likely to be implemented, as noted previously by Carrillo and Chinowsky (2006). The cost benefit index measures the cost difference between traditional and KM-CPS approaches for solving the same problem. Eq. (5) was used to calculate the cost-saving ratio, as follows:

\[
CB\% = \frac{TTC - STC}{TTC} \times 100\% \tag{5}
\]

where \(TTC\) = total cost required by traditional problem solving, as calculated using Eq. (6); \(STC\) = total cost required by the KM-CPS approach, as calculated using Eq. (7); and \(CB\) = cost benefit, given as a percentage (%).

The following equation was used to obtain the value of \(TTC\) (total cost required using the traditional problem-solving approach):
Time effectiveness (TE): measuring the impact of the solution to improve the quality of the work,
Cost effectiveness (CE): measuring the impact of the solution to improve the cost effectiveness of the work,
Quality effectiveness (QE): measuring the impact of the solution to shorten the required duration of the work,
Health and environmental effectiveness (HEE): measuring the impact of the solution to improve the health and environmental performance of the work,
Technology improvement (TI): measuring the impact of the solution to improve the technology innovation related to the work, and
Standards improvement (SI): measuring the impact of the solution to improve the stand/Specification (SPEC) of the construction work.

Data Collection
Data collection ran from June 1, 2005, to August 9, 2010. Initially, 987 problem-solving cases of CECI’s KM-CPS were collected. Some of the problems were primarily computer-related questions (e.g., edition of word processor, rescue of crashed operating system, saving of CAD drawing processing, and so on), which were excluded from further analysis. Only 968 engineering-related problems were selected. Table 1 shows the distribution of the 968 emergency problems in the 10 categories.

The KSM was used to conduct 8,227 questionnaire surveys, with 968 completed cases and 8,198 valid responses received. The valid response rate was 99.73%, an extremely high number attributed to procedure design rigor and strict monitoring of the survey process (see Fig. 3).

Survey results revealed unreasonable responses from a number of respondents. To eliminate the influences of those outliers, the authors used data only from responders in the 5.17–94.83 percentile range for further analysis, excluding from consideration both the top and bottom 50 most beneficial results (for TB, MHB, and CB, respectively). After this filtering process, the authors selected 868 samples for further quantitative analyses.

Validity and Reliability Tests
To ensure the quality of the surveyed results, the following two tests were conducted: (1) validity test, i.e., the factor analysis and item-total correlation were adopted to test the validity of the data, and (2) reliability test, i.e., the Cronbach’s coefficient α was adopted to test reliability. Because the TB, MHB, and CB indices are derivatives of the primary parameters described in Eqs. (1–7), the tests were conducted on the six effectiveness measures that were surveyed with the participants of the 868 cases through KSM. The commercial software SPSS was employed to calculate relevant indicators.
Problem assessed by Diagnosis Module

Non-emergent: Posed in regular CoPs
Emergent: Problem descriptions filled by Questioner:
(1) Emergent classification; (2) Topic of problem; (3) Detail description of problem;
(4) Most relevant CoPs/Subjects; (5) Time limitation (days).

Submission confirmed by Questioner?

Problem posed in EPSU and selected CoPs

Problem dismantled after prescribed time limitation

Questionnaire submitted to Questioner

Questioner accept the responded solution?

Questioner describes reasons for the unsolved problem.

Posed on EPSU again?

Exceed max. pose limitation (3 times)

Report to the KM Committee

Is the posed problem emergent enough for EPSU? (judged by head and manager)

Yes

No

Posed problem removed from EPSU

E-Mail notice to Department Head and relevant CoP Managers

Confirmed

Submission confirmed by Questioner

Disconfirmed

E-Mail notice to Department Head and relevant CoP Managers

Is the posed problem emergent enough for EPSU? (judged by head and manager)

Yes

No

Posed problem removed from EPSU

E-Mail notice to Department Head and relevant CoP Managers

Is the survey complete?

No

Yes

Responder surveying module

Responders parameters survey ($\theta_{RTa}$, $\theta_{HTa}$)

Is the survey complete?

No

Yes

Responsive questionnaire finished

Questioner surveying module

Questioner parameters survey ($N_{D}, M_{C}, M_{K}, M_{T}, \theta_{T}, P_{T}, \theta_{R}, \theta_{L}, \theta_{D}, \theta_{T}$)

Is the survey complete?

No

Yes

E-Mail notice to Department Head for approval

Department Head approves final solution?

No

Yes

E-Mail notice to Questioner

Questioner questions questionnaire finished

Parameters and lesson-learned stored

Benefit quantification

Yes

No

System parameters reported from KM-CPS ($N_{D}, L, N$). Employee unit rate (EUR) provided by Personnel Office.

Fig. 3. Detailed questionnaire surveying flowchart
Table 1. Distribution of the Selected 968 Emergency Problems of the Case Study

<table>
<thead>
<tr>
<th>Number</th>
<th>Type of emergent problem</th>
<th>Count</th>
<th>Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Requests of client</td>
<td>62</td>
<td>6.38</td>
</tr>
<tr>
<td>2</td>
<td>Reaction to accident</td>
<td>10</td>
<td>1.06</td>
</tr>
<tr>
<td>3</td>
<td>Dispute/contract execution</td>
<td>39</td>
<td>4.04</td>
</tr>
<tr>
<td>4</td>
<td>Material and equipment</td>
<td>145</td>
<td>15.00</td>
</tr>
<tr>
<td>5</td>
<td>Safety/environment</td>
<td>42</td>
<td>4.36</td>
</tr>
<tr>
<td>6</td>
<td>Request of engineering information</td>
<td>368</td>
<td>37.98</td>
</tr>
<tr>
<td>7</td>
<td>Completion and transfer</td>
<td>5</td>
<td>0.53</td>
</tr>
<tr>
<td>8</td>
<td>SPEC and criterion</td>
<td>267</td>
<td>27.55</td>
</tr>
<tr>
<td>9</td>
<td>Problems with contractors/subcontractors</td>
<td>14</td>
<td>1.49</td>
</tr>
<tr>
<td>10</td>
<td>Internal process of the firm</td>
<td>12</td>
<td>1.28</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td>968</td>
<td>100</td>
</tr>
</tbody>
</table>

The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was adopted (Kerlinger 1986) as an indicator of construct validity of the questionnaire. Table 2 shows the results, in which the KMO value is 0.776. The principal component analysis shows that the communality values are between 0.516 and 0.758. Almost all of the item-total correlation values are greater than 0.68. Consequently, the testing results show a high construct validity of the questionnaire.

In the second test, the Cronbach’s α was measured with the six effectiveness measures to test the reliability. Table 2 depicts the testing results. The Cronbach’s α coefficient is 0.751, showing a high reliability of the surveyed results according to Nunnally (1978) and Wortzet (1979).

From the results of validity and reliability tests, the authors conclude that the results of the questionnaire surveys are valid and reliable. Such results will be further analyzed both quantitatively and qualitatively in the following subsections to investigate the authors’ insights into the benefits of a KMS.

Benefit Analyses

Quantitative Benefit Analysis

To measure the benefits resulting from the KM-CPS system, the authors calculated the three previously defined measures (TB, MHB, and CB) for all selected cases. The overall quantitative benefits for the firm were found to be the following: (1) 42.22% for time benefit, (2) –251.21% for staff-hour benefit, and (3) –64.28% for cost benefit. Table 3 shows quantitative benefits for each major department. With the exception of time benefit, survey results of the other two measures, MHB and CB, were significantly negative.

Examining surveyed data details in Table 3, the authors found time benefit (TB) to clearly be the most significant benefit, with most design/engineering departments (e.g., structural, geotechnic, hydraulic and environmental, harbor, metro rail transit (MRT), and railway) benefiting significantly from KM-CPS in terms of timely problem solving. Field departments such as branch offices and construction management also benefited. The material testing department benefited the least. Departments attained positive benefits from neither MHB nor CB. This result indicates that KM-CPS may not justify the cost of investment based on the proposed quantitative model. Material testing and construction management departments, respectively, attained the least benefit for these two criteria, followed, respectively, by the railway department and a local branch office.

Qualitative Benefit Analysis

Qualitative benefits of a KMS are less transparent to most users in comparison with quantitative benefits, but are nevertheless significant. Identification of qualitative benefits is difficult. In this case study, qualitative benefits were identified through interviews with CECI engineers/managers who participated in KM-CPS problem solving and through focus group meetings with the managers and members of one or two CoPs each time. The focus group meetings were conducted in the following manner. The requested questions were presented and explained first. This was followed by an open discussion session for participants to share and argue their viewpoints. Finally, specific viewpoints related to qualitative benefits were summarized and presented to the participants for discussion until consensus was reached. The focus group meetings were conducted intensively between March and June 2010 with all CoPs. The managers of all 36 CoPs were interviewed. Primary qualitative benefits identified include the following:

- Increase of firm intellectual assets: during the process of organizational knowledge creation, all participants (including those who read but did not participate in discussions) enhanced their knowledge about the posed problem, with such knowledge potentially useful in the future.
- Resolving previously unresolved problems: in the traditional approach, a taskforce with limited membership and specialty expertise discusses and solves problems; such a format may exclude the real experts (i.e., those who have solved similar problems previously) because of a lack of availability.
- Increase of the Medici effect: integrated with KMS, the KM-CPS can tap into the expertise of the entire firm’s staff and increase intersection frequency to maximize the Medici effect and increase the probability of problem resolution.
- Improved client satisfaction: client satisfaction improves significantly as the KM-CPS shortens the required problem-solving time (this result was supported by nearly all CoP managers), and

Table 2. Cronbach’s α Measurement

<table>
<thead>
<tr>
<th>Item</th>
<th>KMO value</th>
<th>Communality</th>
<th>Item-total correlation</th>
<th>Cronbach’s α</th>
</tr>
</thead>
<tbody>
<tr>
<td>CE</td>
<td>0.776***</td>
<td>0.730</td>
<td>0.775***</td>
<td>0.751</td>
</tr>
<tr>
<td>TE</td>
<td>0.776***</td>
<td>0.758</td>
<td>0.786***</td>
<td>0.776***</td>
</tr>
<tr>
<td>QE</td>
<td>0.776***</td>
<td>0.741</td>
<td>0.797***</td>
<td>0.776***</td>
</tr>
<tr>
<td>HEE</td>
<td>0.776***</td>
<td>0.516</td>
<td>0.683***</td>
<td>0.776***</td>
</tr>
<tr>
<td>TI</td>
<td>0.776***</td>
<td>0.637</td>
<td>0.739***</td>
<td>0.776***</td>
</tr>
<tr>
<td>SI</td>
<td>0.776***</td>
<td>0.595</td>
<td>0.235***</td>
<td>0.776***</td>
</tr>
</tbody>
</table>

Table 3. Quantitative Benefits of the Firm and Major Departments

<table>
<thead>
<tr>
<th>Questioner’s department</th>
<th>Time benefit (TB%)</th>
<th>Staff hour benefit (%)</th>
<th>Cost benefit (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company-wide</td>
<td>42.22</td>
<td>–251.21</td>
<td>–64.28</td>
</tr>
<tr>
<td>Structural</td>
<td>69.15</td>
<td>–184.84</td>
<td>–48.14</td>
</tr>
<tr>
<td>Geotechnic</td>
<td>54.44</td>
<td>–134.43</td>
<td>–50.50</td>
</tr>
<tr>
<td>Hydraulic and environmental</td>
<td>41.25</td>
<td>–250.97</td>
<td>–65.38</td>
</tr>
<tr>
<td>Harbor</td>
<td>56.17</td>
<td>–128.89</td>
<td>–16.05</td>
</tr>
<tr>
<td>Transportation</td>
<td>31.53</td>
<td>–257.50</td>
<td>–69.83</td>
</tr>
<tr>
<td>Metro rail transit</td>
<td>45.65</td>
<td>–184.20</td>
<td>–26.75</td>
</tr>
<tr>
<td>Railway</td>
<td>51.76</td>
<td>–291.90</td>
<td>–85.26</td>
</tr>
<tr>
<td>Mechanical</td>
<td>24.54</td>
<td>–113.56</td>
<td>–24.26</td>
</tr>
<tr>
<td>Electrical</td>
<td>24.80</td>
<td>–310.90</td>
<td>–62.23</td>
</tr>
<tr>
<td>Material testing</td>
<td>3.98</td>
<td>–282.03</td>
<td>–155.66</td>
</tr>
<tr>
<td>Construction management</td>
<td>47.95</td>
<td>–328.41</td>
<td>–105.51</td>
</tr>
<tr>
<td>Taichung branch</td>
<td>29.25</td>
<td>–343.87</td>
<td>–84.38</td>
</tr>
<tr>
<td>Kaohsiung branch</td>
<td>41.99</td>
<td>–253.40</td>
<td>–44.95</td>
</tr>
</tbody>
</table>
• Improved sense of belonging; a sense of belonging to an organization is a holistic property that promotes firm competitiveness; under such an environment, KM-CPS engineers/managers and other staff share work pressures and the pleasure of problem resolution, which improve the sense of belonging among all organization employees.

Discussion
Some findings of the case study are discussed in the following to provide managers of construction organizations the authors’ insights into KMS implementation.

Advantages of KMS Implementation
The case study results clearly shows time saving to be the primary quantitative benefit of the KM-CPS relative to traditional problem solvers. Based on survey results, a 42.22% time advantage was achieved based on 868 analyzed problem solving cases. The authors found that the estimated time required for problem solving was 4.64 and 2.68 days for the traditional and 2.68 KM-CPS approaches, respectively.

A new paradigm of problem solving was established. Unlike the traditional problem-solving approach with local intelligence, of a small task force, the KM-CPS adopts the organization-wide intelligence supported by all employees of the organization. It can be explained through the following example. A pavement crack problem of a asphalt concrete road construction project in Kiemen Island (a remote island that is 270 km west to Taiwan) was solved by an engineer of the branch office in Hualien County (located in the eastern coast of Taiwan). Furthermore, the staff of CECI provided many solutions after office hours. This was especially true for site engineers who work on construction sites and usually cannot access the Internet during the day.

Furthermore, knowledge is leveraged because the problem-solving process is transparent to all members of the CoP, and all participants share the lesson learned from problem solving. The participants can apply such knowledge to solve other problems encountered in the future. The Medici effect, manifested by participants in different contexts, amplifies such leverage of knowledge. It improves the organization’s competitiveness further, even though its benefit is difficult to quantify.

Potential Issues
The most concerning issue for management is related to the negative benefits in terms of both cost and staff hours resulting from the case study, which indicates potential disadvantages of adopting a KMS. It should not be surprising that the quantitative model was defined based on parameter values in the traditional problem-solving approach. Given that the KM-CPS involves the participation of nearly all firm employees in problem solving, staff hours and costs tend to be higher. Such negative benefits need to be improved to justify and sustain the KMS. This issue also suggests that a mechanism to pinpoint the desired solution (probably from historical lessons learned) before entering the KM-CPS process is required to reduce staff hours.

A second issue induced by KMS implementation is the extra time needed from the participants of the KM-CPS. While interviewing department managers, some complained that their staff took greater interest in solving KM-CPS problems than in their regular jobs. Clear ground rules for KMS participation should be defined and announced to the members of CoP such that participation does not conflict with departmental requirements.

Another issue is related to cultivating the culture of knowledge sharing. In the case of the engineering consulting firm, a grading system was devised to encourage the participation of problem-solving activities of the KM-CPS. Some participants have provided many less useful responses to the posed questions to earn credits given by the grading system. Such an action not only spends the time of the responder him/herself, but also increases the difficulty for the questioner in arriving at the final solution because he/she must read more information. As a result, the reinforcement mechanism for participation in KM-CPS problem solving should be carefully reviewed.

Improvement Suggestions
In spite of the significant time benefit of KM-CPS relative to the traditional problem-solving approach, the 2.68-day problem-solving time was still less than ideal for their clients, according to manager opinions expressed in focus group meetings. Many managers suggested that the most significant time wastage occurred in waiting for the real domain experts (i.e., staff who had previously solved similar problems). This suggests that companies should identify and employ a quick and effective method to identify the most appropriate experts. An expert map that characterizes the expertise of the domain experts is desired.

To improve the cost and staff hour benefits, some managers suggested that lessons learned should be recorded and provided instead of electronic files currently stored in the knowledge base of the KMS. Other managers remarked on the inefficient nature of the current KMS search engine. According to one senior engineer participant in the focus group meeting, “Simply providing available files is not particularly helpful to engineers, but rather providing the exact location of the needed knowledge in the document is what is needed.”

Conclusions
Given that construction organizations use knowledge management systems extensively, organization managers must address the essential question of whether implementing the KMS is cost effective. Few articles in the literature have reported on KMS implementation benefits and even fewer have addressed the quantitative measures of KMS performance. This case study reveals a five-year comprehensive benefit survey on implementation of a specialized KMS, KM-enabled problem solver at a major engineering consulting firm. Quantitative models are designed to measure the tangible benefits (time, cost, and staff hours) of greatest concern. Case study results show that the only significant quantitative benefit among the three tangible benefit measures was in terms of time saved. Cost and staff hour benefit measures tend to disfavor adoption of the KMS.

The research team identified major problems with the current KM-CPS using focus group meetings with KMS communities of practice managers. These included time wasted waiting for real domain experts, failure to record/store historic lessons learned properly for retrieval and reuse, and difficulties locating needed knowledge even when appropriate documents are found. Based on this result, a more proactive approach that is able to improve the previously noted problems should be provided.

Apart from tangible measures, the interviewed managers widely approved of the qualitative benefits of KM-CPS, which included the increase of firm intellectual assets, resolution of previously unresolved problems, increase of the Medici effect, improvements in client satisfaction, and enhanced sense of belonging in the organization.
Acknowledgments

The National Science Council, Taiwan, under project No. NSC 95-2221-E-216-049, partially supported the founding of this research project. The authors give sincere appreciation to the sponsor, CECI, Engineering Consultants, Inc., Taipei, provided the valuable case study information presented in this paper. The authors express sincere appreciation for their contribution.

References


