行政院國家科學委員會專題研究計畫 成果報告

工程顧問業知識管理系統效益評估及改善模式之研究(II)
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行政院國家科學委員會補助專題研究計畫 **■ 成 果 報 告**
□期中進度報告

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計畫參與人員： 吳誌銘、連偉志

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中　華　民　國　97 年　9 月　9 日

一、摘要

(一) 計畫中文摘要。(五百字以內)

過去幾年來政府大力推動 eTaiwan 計畫，希望透過資訊通訊技術的應用，將台灣的產業提升為知識經濟型產業。營建工程為一以經驗為基礎之專業，從過去執行專案中累積與發掘之營建工程知識為各營建業者(包括業主、設計者、施工單位及營建管理顧問)確保未來專案成功之基石，因此營建業也屬於一種特殊的「知識經濟」產業。營建業為一知識密集產業，其知識之獲取、創新、貯存、分享與再利用等知識管理活動與公司之產業競爭力息息相關，因此如何有效地衡量知識管理系統(KMS)之效益，並具以研擬改善策略，為公司主管階層的重要課題。經過文獻調查發現目前知識管理系統績效評估之研究甚為缺乏，更未見任何有關知識管理效益之量化分析報告。究其原因，主要在於知識產品(Artifact)之價值甚難評估，而知識活動之效益更難以定義。本研究旨在提出一套 KMS 效益之量化評估方法，並以台灣地區大型營建業(含工程顧問業及營造業)為個案對象，以實證研究之方式，針對案例公司 KMS 中之實際案例，分別就知識管理效益、知識管理活動及知識創新模式等課題進行個案分析，以量測 KMS 系統及相關知識活動之實質效益。本研究計畫預定以三年為期：本年度之研究在建立「知識管理效益評估模式」，並選擇國內較具代表性之工程顧問業做為個案研究對象，進行「知識管理效益評估模式」之驗證，完成工程顧問業 KMS 系統量化效益分析。

關鍵字：知識管理、知識社群、績效衡量、顧問公司

（二）計畫英文摘要。（五百字以內）

In the past few years, the Taiwan Government has spent tremendous efforts in promoting the eTaiwan project, which emphasizes on widely application of the Information and Communication Technology (ICT) to transform the industries from traditional to knowledge-based ones. Construction has been conceived as an experience-based discipline. Knowledge learned from previous projects plays important role in successful performance of future projects. This has made construction an ideal industry for knowledge-based economy. The performance of knowledge activities such as acquiring, creating, storing, sharing, and reusing of knowledge have significantly impacts on the competitiveness of the firm. As a result, the effectiveness measurement and improvement of a knowledge management system (KMS) become a key issue for top managers of the firm. Very limited works were found from literature survey on the benefit measurement of KMS. It was due to the difficulty for identification of the knowledge artifacts and quantification of their benefits. This research aims at developing a quantitative benefit measuring method for KMS. Several leading firms from local construction industry will selected as the industrial partners for implementation of the proposed method. Real world cases of KMS activities collected from the KMS of case firms will be used for study in light of benefits, behaviors, and models of knowledge creation activities. The proposed research is scheduled for three years. The major work of this year is to propose a knowledge value adding model (KVAM) for performance measurement of the community of practice (CoP) in the knowledge management system (KMS) of an A/E consulting firm.

Keywords: Knowledge management, community of practice, performance measurement, A/E firm.

二、動機與目的

Construction has been conceived as an experience-based industry [1]. Knowledge and experiences accumulated from previous works play a very important role in successful performance of new projects. There are more and more construction organizations (including owners, developers, A/E firms, contractors, and construction management firms) implement the knowledge management (KM) initiatives in their organizations to create, capture, record, retain, retrieve, reuse and revise the knowledge generated from the staffs, internal processes, and external customers. However, the assessment of the returns of KM initiatives is lagging behind. In other words, organizations spent a lot of efforts and resources in establishing their knowledge management infrastructure, both for hardware and software, while fewer efforts were invested to measure the results of their KM endeavours [1]. Very little literature is found on measuring the performance of a knowledge management system (KMS) due to a key problem: lack of effective and quantitative methods for measuring values resulted from the KMS [2]. Without such methods, KM managers could not determine the values generated from a KMS, nor can he/she plan effective strategies to improve the performance of KMS [3].

This paper presents the development of a quantitative performance measurement model for the generic Communities of Practice (CoPs) in a KMS. Such a model aims at tackling general types of KM activities that generate values to the organization's intellectual assets. To achieve this goal, the value-adding activities/processes of knowledge management initiatives are identified and modelled first. Then, the quantitative methods are developed to calculate the values generated from the identified processes. A Knowledge Value-Adding Model (KVAM) is proposed to meet these two ends. An internet-based web service system, namely Knowledge Value-Adding System (KVAS) is developed to implement the proposed KVAM. A case study is conducted on a leading local A/E firm to demonstrate the proposed KVAM and test the applicability of KVAS. Finally, discussions on the applicability and system limitations of the proposed method are addressed. The proposed method aims to offer the KM managers of the firm and the CoPs a useful tool to measure the values of their KM initiatives, so that management efforts can be planned and tested by monitoring the increased/decreased values resulted from those efforts. Thus, effective strategies for performance improvement of the KMS can be identified and implemented.

三、文獻探討

Previous Works on Quantitative Performance Measurement of KM

Although there was little on performance measurement of KMS in the literature, some relevant works were found including the quantification of intellectual assets (IA), performance measurement of KMS, and quantification of benefits resulted from KMS. This section revisits some of the important works.

Quantification of intellectual assets

The values generating from a KMS constitutes a part of the organization's intellectual assets (IA), the quantification of IA provides a model for quantitative performance evaluation of a KMS, too. Chang and Wang [4] summarized several existing methods for valuation of intellectual assets and categorized them into three groups: (1) first generation indexes—including Navigator, BSC, and Intangible Asset Monitor; (2) second generation indexes—including Intellectual Capital Index (IC Index), Intellectual Capital Audit (IC Audit); and (3) financial measures—including market-to-book ratio method, Tobin's q method, and Economic Value Added (EVA) method.

For the first generation, the Navigator classifies intellectual capitals into various types and measures the intellectual capitals with proxy variables that are multiplied with pre-defined weightings. The BSC method views the intellectual capital from four perspectives: (1) learning and growth; (2) internal processes; (3) customer; (4) financial. Key performance factors (KPIs) are defined in each perspective of BSC. The intellectual capital is then measured with values of KPIs through an aggregation process. The Intangible Asset Monitor (IAM) differentiates intellectual capitals into various types and determines measuring dimensions such as growth, efficiency, etc. Finally, an intellectual capital report is generated for management purposes.

Both IC Index and IC Audit methods in the second generation try to relate the intellectual indexes with financial ratios and convert into a single indexing system. In the financial measuring methods, the Market-to-book ratio measures the intellectual assets by subtracting the tangible asset value from the market value. This method is highly influenced by the stock price in the market. The Tobin's q method is based on the theory proposed by the Nobel Economic Prize winner James Tobin from Yale University. The Tobin's q is defined as the market value of a firm's assets (a firm's productive resources) divided by replacement value (current cost of replacing the firm's assets) of the firm's assets. The EVA is a method of performance evaluation that adjusts accounting performance for investors' required return on investment. The EVA measure intellectual capital by the equation: "EVA=Net earning after tax-(weighted average capital cost × (total asset – liquid asset))".

All of the above methods valuate the intellectual assets from viewpoint of the organization (or corporate) level. They can be conceived as the macro measures for benefits of a KMS. However, the overall indexes may not reflect the actual benefits generated solely by KMS. For instance, a strategic decision of top manager may cause overrun of a project, which is not due to KMS. A better approach is to develop a specific quantification method for KMS that is not affected by factors other than knowledge management activities.

Performance measurement of KMS

Swaak et al. [5] conducted as survey and concluded that there are two major measurement approaches related to knowledge management results: (1) questionnaire approach; (2) multiple indicators approach. Within the 'questionnaire approach', a questionnaire with closed and open questions, completed by participants of a KMS reveals the profile of an organization. Usually, the profile is used in subsequent interviews and workshops. Within this approach, major concepts are 'extent of knowledge sharing' and 'learning potential' of an organization. The 'multiple indicator approach' roughly makes a distinction between 'customer capital', 'innovation capital', 'financial capital', 'internal business processes', and 'human capital'. For each category, a large number of indicators—mostly objective and quantitative—are collected.

An eight-step framework to create performance indicators for knowledge management solutions was proposed by del-Rey-Chamorro et al. at Cambridge University [6]. The framework consists of three stages: (1) strategic level—comprising of measures that evaluate the organization's goals; (2) intermediate level—comprising indicators that link the process performance indices at the operational level to the business performance indicators in the strategic level; and (3) operational level—comprising indicators that represent the measurable process performance of a KMS. del-Rey-Chamorro et al.'s work was similar to the BSC approach [8] reviewed previously for quantification of IA, which is also limited to the organizational measurement.

Bassion et al. addressed that in developing a conceptual framework for measuring business performance in construction should take into account the organization's business objectives [7]. They also conducted empirical experiments on two case construction firms in UK. A systematic analysis model based on IDEF0 was also developed for the proposed framework.

Bassion et al.'s work was theoretically based on some existing performance measurement systems such as Balanced Scorecard (BSC) [8], European Foundation for Quality Management (EFQM) excellence model [9], and Key Performance Indicators (KPI) [10]. The above systems provide useful indicators that can be adopted for performance evaluation in the present research.

Benefit quantification of KMS

Yu et al. proposed a set of quantitative models to quantify the benefits resulted from a KMS of an A/E consulting firm [2]; those benefits include cost, time, and man-hour savings. Their quantitative models were formulated based on the comparison of problem-solving processes between the traditional approaches and the KMS approaches. According to their study on 17 problem-solving cases, averagely 63% for time benefit, 73.8% for man-hour benefit (MHB), and 86.6% for cost benefit were achieved. Their research also found that KMS provides a better communication platform for KMS participants so that The Medici Effect can happen [11]. Moreover, KMS also provides a knowledge based system that expedites the "combination" conversion in Nonaka's knowledge creation spiral [12].

Even though Yu et al.'s work has established the quantitative models for measuring the performance of knowledge management activities, there exist two limitations in their models: (1) the models were developed only for problem-solving activities, other types of KM activities were not included; (2) the models were developed for a specialized CoP called SOS (Emergent Problem-Solving Community), generic CoPs were not included. A more general method is desired to tackle the performance measurement in a generic CoP.

四、研究方法

Theoretical Backgrounds of KVAM

As mentioned above, previous work of the research team has quantified the benefits of a special type of Community of Practice (CoP), however, no method has yet been developed to quantify the KM performance of a generic CoP. Before proposing the KVAM, the theoretical backgrounds are addressed in this section.

Knowledge creation model

The original knowledge creation model was proposed by Nonaka called "spiral of organizational knowledge creation" in his Dynamic Theory of Organizational Knowledge Creation [12]. The concept of Nonaka's spiral of organizational knowledge creation is depicted in Figure 1, where the vertical axis discriminates the knowledge type into "explicit" and "implicit". The horizontal axis differentiates the ontology of knowledge creating entities, e.g., individual, group, organization and inter-organization. There are four modes for knowledge conversion in the process of knowledge creation: (1) Socialization—transferring personal tacit knowledge to tacit knowledge of the other individual; (2) Externalization—transferring individual's tacit knowledge to explicit form so that the public can access and utilize; (3) Combination—transferring explicit knowledge to explicit knowledge by combining two or more sources of codified explicit knowledge to generate a new entity of explicit knowledge; (4) Internalization—transferring explicit knowledge to tacit knowledge of individual. Among those, the socialization is related to group process/ organization culture.

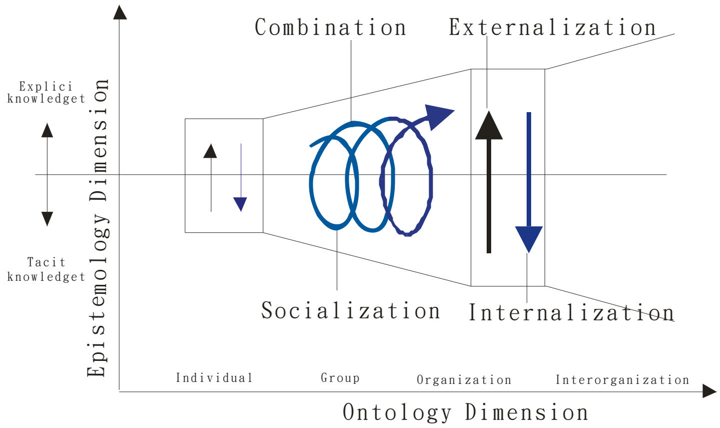

Figure 1 Spiral of organizational knowledge creation [12].

Nonaka addressed that the generation of new knowledge happens in the four modes of knowledge conversion, which constitutes the essential value of an organization. Nonaka's theory was supported by Johansson in his theory of "Medici Effect" [11], where the knowledge creation activities are more productive as individuals of different contexts intersect each other. It is believed that the modern design of CoPs was a realization of the "intersection field" in the Medici Effect.

Knowledge chain model

A further step of Nonaka's Knowledge Creation Theory is the Knowledge Chain Model proposed by Holsapple and Singh [13]. The Knowledge Chain Model identifies five major knowledge manipulation activities (primary activities) that occur in various patterns within KM episodes: acquisition, selection, generation, internalization, and externalization. In addition, there are secondary activities that support and guide the performance of primary knowledge manipulation activities: measurement, control, coordination, and leadership. An organization may possess the best knowledge resources and the best knowledge manipulation skills, but they are of no use until they are effectively applied during the conduct of KM [14]. The Knowledge Chain Model thus links the competitiveness of the organization with the value generation through the knowledge processing chain: acquisition → selection → generation → internalization → externalization. The proposed KVAM adopts the value generation concept similar to the Knowledge Chain Model.

Knowledge value added theory

The Knowledge Value Added theory was proposed by Housel and Bell [15] and depicted in

Figure 2. In Figure 2, "P" stands for individual that processes the input knowledge (X) and generates output value (Y). The process "X→P→Y" can be viewed as a value-generating KM activity in the Knowledge Chain. The Knowledge Value Added theory states that: the value generated by "P" is proportionate to the change of state from X to Y, i.e., the amount of knowledge being created. As a result, the value of the KM activity can be measured by the amount of knowledge created (or the difference of knowledge content between X and Y in Figure 2). Three propositions were made for KVA theory: (1) As "X≡Y", there is no value added; (2) the value is proportionate to the amount of change; (3) the amount of change can be measured by the utilization of knowledge [15].

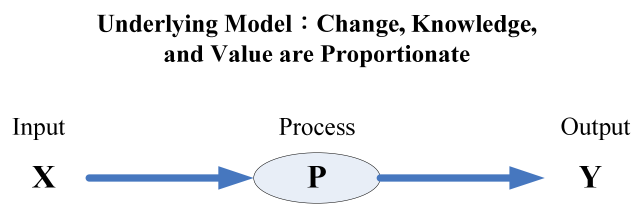

Figure 2 KVA process [15].

The Knowledge Value Added theory provides a promising model for quantitative performance measurement of a CoP as long as the value-adding activities are identified with the quantified amounts of knowledge changes.

Proposed Knowledge Value Adding Model (KVAM)

This section describes the proposed KVAM for quantitative KM performance measurement. The proposed KVAM is based on theoretical backgrounds described in the last section.

Identification of value-adding KM activities

Before building the KVAM model, field trips were conducted by the research team to a local leading A/E consulting firm, CECI [18], of Taiwan. By investigating the records of KMS in the case A/E firm, it is found that KM activities of the CoPs are diversified. However, two major types of KM activities were identified: (1) knowledge sharing activities—the ones initiated by the participant who is willing to share his/her knowledge, experiences, and viewpoints on a specific topic; (2) problem-solving activities—the ones requested by whom encounters unsolved problem and asks for solutions from others. Usually, the second type of KM activities is constrained with time limitation due to the urgency of problem, while those of the first type are loose in time frame. Both types of KM activities contribute to the knowledge generation of KMS. However, the value adding processes are different.

The model

Basic model

Based on the theoretical backgrounds addressed above, a basic model of KVAM is proposed as shown in Figure 3.

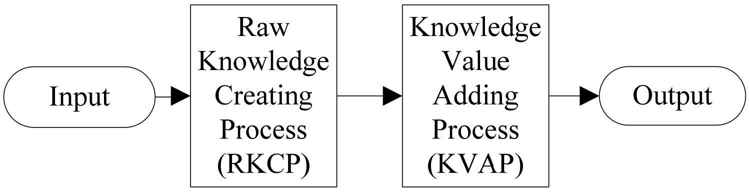

Figure 3 Basic model of KVAM

In Figure 3, the basic model consists of two stages of human involvement (related to the "P" in Knowledge Value Added theory): (1) Raw knowledge creating process (RKCP)—performed by the initiator of a KM activity; (2) Knowledge value adding process (KVAP)—performed by the participants/respondents of a topic in the CoP. As mentioned in Nonaka's Knowledge Creation Theory, the first stage may involve four modes of knowledge conversion including socialization, externalization, combination and internalization. The second stage is related to the Knowledge Chain Model, in which the knowledge generates values only when it is applied or utilized by the other individuals. The value of the "Knowledge Value Added (KVA)" is then measured by subtracting the amount of knowledge of the input from that of the output. This is performed by multiplying the fuzzy terms of the two separate stages.

As the basic model of KVAM is established, two types of KM activities should be handled separately according to the characteristics of raw knowledge and value adding processes. This will be described in the following sub sections.

Measuring KVA of knowledge sharing activities

For the knowledge sharing activities, the raw knowledge creation are classified into five categories (RKC terms, RKCTs) according to the level of value adding: (1) non-relevant—the knowledge shared is not relevant to the theme of the CoP, and thus the KVA is very low; (2)

data—the very primitive form of knowledge without further processing, usually in forms of numbers or words; (3) information—the higher level of knowledge than data, which is generated by processing the data for a specific purpose; (4) knowledge—the even higher level of knowledge that contains information with action indication, i.e., the actionable information; (5) wisdom—the highest level of knowledge that is crystallized by applying the knowledge to real world problem-solving and gaining experiences, i.e., knowledge with evaluation or lessons-learned.

Similarly, the knowledge value-adding processes are also classified into five categories (KVA terms, KVATs): (1) no-value-added—no value is generated by the process; (2) get—a small amount of value is generated through the obtaining or retaining (socialization) of knowledge; (3) use—a medium amount of value is generated through the application (or combination) of the obtained knowledge; (4) learn—a large amount of value is generated through internalization of the used knowledge; (5) contribute—the highest amount of knowledge generated by contributing new entity of knowledge to the raw knowledge. The complete KVA model for knowledge sharing activities is depicted in Figure 4.

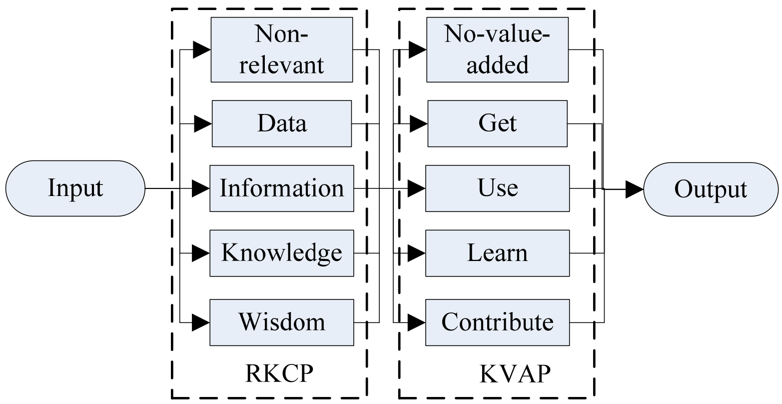

Figure 4 KVAM for knowledge sharing activities

Measuring KVA of problem-solving activities

For the second type of KVA activities (problem-solving activities), the raw knowledge are classified into five categories (RKCTs): (1) non-significant—the posed problem is of no significance to the CoP; (2) low significance—the posed problem is relatively low significance to the CoP; (3) medium significance—the posed problem is of medium significance to the CoP; (4) high significance—the posed problem is of high significance to the CoP; (5) most significant—the posed problem is belong to the most significant problems to the CoP.

On the other hand, the knowledge value-adding processes are also classified into five categories (KVATs): (1) no contribution—no value is generated by the process; (2) low contribution—a small amount of value is generated through the obtaining or retaining (socialization) of knowledge; (3) medium contribution—a medium amount of value is generated through the application (or combination) of the obtained knowledge; (4) high contribution—a large amount of value is generated through internalization of the used knowledge; (5) highest contribution—the highest amount of knowledge generated by contributing new entity of knowledge to the raw knowledge. The complete KVA model for problem-solving activities is depicted in Figure 5.

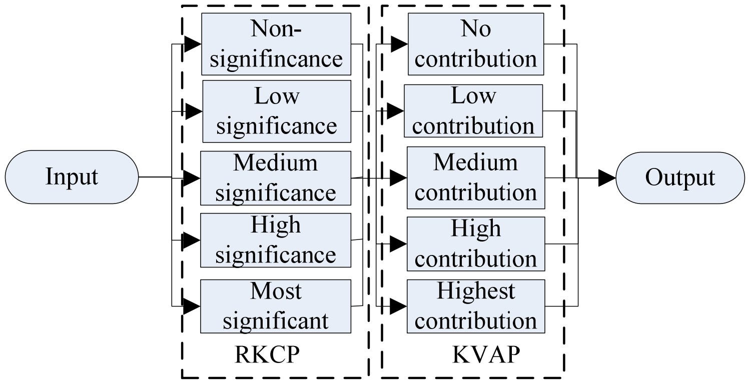

Figure 5 KVAM for problem-solving activities

Assessment of fuzzy membership functions

In order to quantify KM performance, it is required to assess the membership functions of the fuzzy linguistic terms associated with the RKCTs and KVATs described previously. In this research, the questionnaire survey is adopted first to assess the subjective preferences on the terms with memberships; then the Kohonen Feature Map [16] is employed to automatically construct the membership functions. In assessing the subjective preferences of the KM manager of each CoPs toward the RKCTs and KVATs. KM descriptions were presented to the managers of CoP, and then they were asked to determine appropriate terms and the associated scores (0~100) that best reflect the RKCTs and KVATs. The data sets (term, score) are used for self-organization of Kohonen Feature Map as shown in the following:

The Kohonen learning rule consists of two stages:

Similarity matching stage:

$$\left|x - \hat{w}_i^k\right| = \underset{1 \le j \le n}{Min}\left\{\left|x - \hat{w}_j^k\right|\right\}, \tag{1}$$

where the most similar cluster for input data x is found to be the ith cluster by minimizing the difference between x and the center of the cluster ($\hat{w}_i^k$), where superscript k represents the kth iteration and $\hat{w}$ means a normalized value of the cluster center (w).

Updating stage:

$$\hat{w}_i^{k+1} = \hat{w}_i^k + \eta^k \left(x - \hat{w}_i^k\right),$$

$$\hat{w}_j^k = \hat{w}_j^k \text{, for } j = 1, 2,..., n \quad j \neq I, \tag{2}$$

where η^k is a proper learning coefficient at the kth iteration. In the updating stage, the center of the ith cluster, the *winner* cluster, at the kth iteration ($\hat{w}_i^k$) is adjusted toward the incoming training data, x. The rest of the clusters are kept the same. Since only the winner cluster is adjusted, the rule is also called the winner-takes-all learning rule.

The above learning rule can be used to determine the means of the membership functions associated with the input and output term nodes. It is basically a clustering process which gathers similar data together and determines the center of those data. Each of these similar groups is identified as a fuzzy term. The center of the group represents the mean of the fuzzy term. The next step is to find the spread (width) of the bell-shaped membership function. In this research, the first-nearest-neighbour heuristic proposed by Lin and Lee [17] is adopted here to determine the spread of the membership function. The first-nearest-neighbour heuristic can be described as follows:

$$\sigma_i = \frac{\left|m_i - m_{nearest}\right|}{\gamma}, \tag{3}$$

where m_i and $m_{nearest}$ represent the first incoming data and the center of cluster i respectively, and γ is the overlap ratio which represents the overlap between two adjacent fuzzy terms.

KVA calculation

The KVA models for two different types of KM activities in a CoP have been established in previous sections, the remained tasks are the calculations of knowledge changes between input and output. This can be performed by aggregation of the amplitudes (of changes) in the two stages of KVA process. As the amplitudes are represented as the linguistic RKCTs and KVATs as shown in Figure 4 and 5, an intuitive way for the aggregation is Fuzzy Arithmetic. It is very straightforward to perform the aggregation process with Fuzzy Multiplication of fuzzy numbers associated with the RKCTs and KVATs. Take the i^{th} KM activity for example, assume that the fuzzy numbers of the RKCTs and KVATs are $\overline{A}_i$ and $\overline{B}_i$, respectively; then, the KVA can be calculated by the following equation:

$$KVA = {}^{\alpha}A \times {}^{\alpha}BKVA = {}^{\alpha}A \times {}^{\alpha}B \quad , \qquad (4)$$

where KVA_i is the estimated knowledge value added (crisp) of the i^{th} KM activity through the KVA process; and $\overline{A}_i$ and $\overline{B}_i$ describes the knowledge changes in the RKCP and KVAP.

To aggregate the *KVA*s resulted from multiple KM activities, the Fuzzy Addition operation can employed as shown below:

$$KVA = {}^{\alpha}A \times {}^{\alpha}BKVA = {}^{\alpha}A \times {}^{\alpha}B \quad , \qquad (5)$$

where KVA_{total} is the aggregated knowledge value added of the n KM activities; and KVA_i represents the KVA of the i^{th} KM activity.

With the KVA models and the computational algorithms described above, the proposed KVAM is ready to quantify the performance of CoPs in a KMS. In the following section, a case study is conducted to demonstrate the applicability of the proposed KVAM.

五、結果與討論

Case Study

The proposed KVAM is applied to the 5 selected CoPs of a leading local A/E consulting firm, CECI, Taiwan [18].

Background of the case A/E firm

The CECI is one of leading A/E firms in Taiwan. It was established in 1969 primarily for the purpose of promoting Taiwan's technology and assisting in the economic development of Taiwan and other developing countries. The number of full-time staffs of the firm is about 1,700. Among those around 800 are in-house staffs in headquarters located in Taipei, the other 900 are allocated in branches and site offices around the island. Headquarters, braches, and site offices are connected by Intranet.

The structure of the case A/E firm consists of five business groups: (1) Civil Engineering Group; (2) Railway Engineering Group; (3) Electrical and Mechanical Engineering Group; (4) Construction Management Group; and (5) Business and Administration Group. Each business group includes several functional departments. The annual revenue of case A/E firm is around 4 billion TWD (128 million USD). According to the information disclosed by the firm, more than 1,700 A/E projects were finished in the past thirty years. Totally volume (construction budget) of the finished projects exceeds 300 billion USD.

Selected KMS and CoPs

The implementation of KMS in the case A/E firm started in 2001. Unlike most of other KMS implementations, the case A/E firm chose to develop the KMS completely by their own staffs without help from external consultants. At the beginning, the KMS was proposed by the Department of Business and Research. Soon, it was realized that engineers of Department of Information Technology should be included in order to resolve the technical problems encountered in implementation of prototype system. Commercial software, MS™ SharePoint® was adopted as the infrastructure of the KMS. The system development took one year to complete the prototype.

The prototype KMS began to operate after one year of the project commencement. It was found quickly that development of software KMS is not a tough job compared with the building of the culture and atmosphere for successful operation of the KMS. Totally 42 CoPs were established. The number of CoPs is varying based on a set of entry-and-exit criteria. That is, continuous evaluation of the CoPs is performed to determine whether it should be remained or shut down. The manager of CoP is in charge of all activities for promotion of the knowledge creation in that CoP. Incentives were provided by the company to stimulate the establishment of knowledge sharing atmosphere.

In order select appropriate CoPs with right cultural and enthusiasm in knowledge sharing, interviews were conducted by the research team during March 2007~May 2008 to meet with the managers of the CoPs. Finally, five CoPs were selected: (1) Steel Community (SC, associated with Structural Design Department); (2) Rail-Highway-Airport (RHA, associated with Transportation and Civil Department); (3) Supervision Art (SA, associated with Construction Management Department); (4) Digital Globe (DG, associated with GIS Department); and (5) Geotech (GT, associated with Geotechnic Engineering Department).

Questionnaire survey

In order to construct the fuzzy membership functions of the RKCTs and KVATs in the RKCP and KVAP, questionnaires were provided with the managers of the five selected CoPs. Total number of KM cases selected for questionnaire survey is 497, of which 492 responses are valid with almost 99% of valid samples (see Table 1). The data sets collected from questionnaire are then used for Kohonen learning to obtain the means of fuzzy membership functions associated with the associated RKCTs and KVATs. The results of Kohonen learning for the RKCTs and KVATs are shown in Table 2 and Table 3, respectively.

Table 1 No. of KM cases selected for questionnaire survey

Sample statistics CoP	2005		2006		Total	
	Sampled	Valid	Sampled	Valid	Sampled	Valid
Steel Community	0	0	117	116	117	116
Rail-Highway-Airport	0	0	160	159	160	159
Supervision Art	0	0	76	74	76	74
Digital Globe	37	37	22	21	59	58
Geotech	0	0	85	85	85	85
Total	37	37	460	455	497	492

Table 2 Means of fuzzy membership functions for RKCTs

CoP	RKCTs				
	Non-relevant	Data	Information	Knowledge	Wisdom
Steel Community	5.0	23.1	46.7	65.1	95.0
Rail-Highway-Airport	5.0	30.5	49.3	73.5	95.0
Supervision Art	5.0	30.5	60.2	81.8	95.0
Digital Globe	5.0	26.7	47.9	69.2	95.0
Geotech	5.0	31.6	50.0	68.2	95.0

Table 3 Means of fuzzy membership functions for KVATs

CoP	KVATs				
	Non-relevant	Data	Information	Knowledge	Wisdom
Steel Community	5.0	31.8	43.3	60.5	95.0
Rail-Highway-Airport	5.0	25.3	49.5	76.5	95.0
Supervision Art	5.0	34.8	61.8	83.6	95.0
Digital Globe	5.0	35.7	56.3	73.8	95.0
Geotech	5.0	20.4	43.2	68.7	95.0

It is noted that the upper- and lower bounds of fuzzy means for both the RKCTs and KVATs are normalized to be 5.0 and 95.0, respectively, to avoid the affects of biased assessment. Moreover, the average KVA values for all CoPs are set to "50" to avoid favoring specific CoP.

The KVA values are calculated with Eq. 4. The calculated results are stored in a look-up table for convenient use. Table 4 shows an example of the KVA look-up table by multiplying the RKCTs with KVATs in the KVAM. For example, the raw knowledge of “information” (RKCT) combined with an action of “use” (KVAT) can generate a KVA value of “20.2” to the organization. Similarly, the raw knowledge of “wisdom” (RKCT) combined with an action of “contribute” (KVAT) can generate the highest KVA value of “90.3” to the organization.

Table 4 KVA look-up table (CoP: Steel Community)

RKC terms / KVA terms	Non-relevant	Data	Information	Knowledge	Wisdom
No-value-added	0.3	1.2	2.3	3.3	4.8
Get	1.6	7.4	14.9	20.7	30.2
Use	2.2	10.0	20.2	28.2	41.2
Learn	3.0	14.0	28.2	39.3	57.4
Contribute	4.8	22.0	44.3	61.8	90.3

System implementation

A web service system called Knowledge Value Adding System (KVAS) is developed to implement the proposed KVAM. The KVAS provides desired quantitative performance information to the KM managers including: the KM performance of the individuals, the CoPs, and the departments; the performance comparison among the individuals, the CoPs, and the departments; it also provide a monitoring of KM performance according to the firm’s average. Figure 6 and 7 show examples of KVAS interfaces.

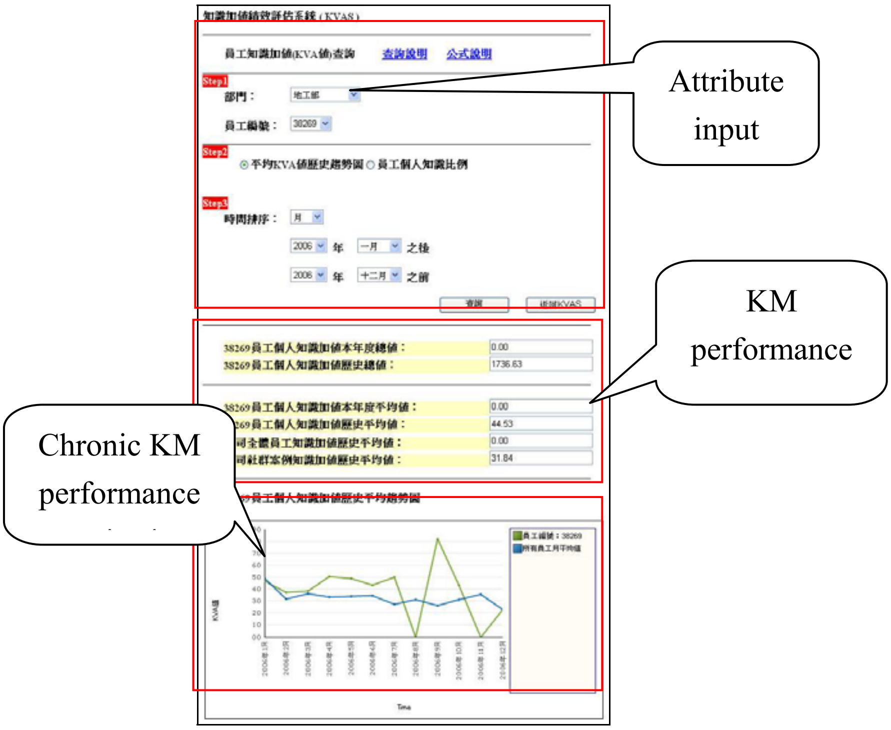

Figure 6 Chronic monitoring of KVA in KVAS (individual vs. firm's average)

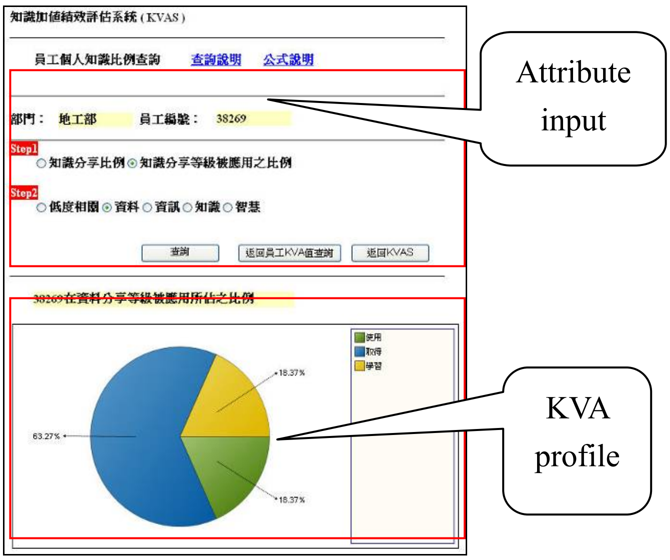

Figure 7 Profile of KVA terms in KVAS

System testing

Traditionally, the KM performance of the case firm was evaluated manually by the managers of departments of the case firm. The evaluation was based on some objective information of the individual in a period of time, such as the number of participations in KM activities (both for knowledge sharing and problem-solving activities) by the individual. In order to verify the proposed system, the KVA values calculated by KVAS are tested with the traditional manual evaluation scores provided by the case firm. The statistical regression is adopted to test the goodness-of-fit of the model. The index R^2 value > 0.6 was suggested for acceptance of the regression model [19]. An example of testing result is shown in Figure 8, where every spot represents a data set (traditional evaluation score vs. KVA value) of an individual staff in the firm. The closer the spot is to the regression line means the more correlated between the traditional evaluation score and the KVA value. The testing results of all selected CoPs are shown in Table 5. It is noted that, except for the Geotech CoP, all other four CoPs have passed the testing. The Geotech CoP has a nearly acceptable R^2 value (0.5910). It implies that the KVAM generally confirms traditional manual approach for KM performance measurement.

Table 5 Regression testing of KVAM vs. traditional manual approach

CoP	No. of KM activities	R^2	Goodness-of-fit
Steel Community	407	0.6519	acceptable
Rail-Highway-Air port	754	0.8454	good
Supervision Art	537	0.9263	excellent
Digital Globe	76	0.8437	good
Geotech	1605	0.5910	unacceptable

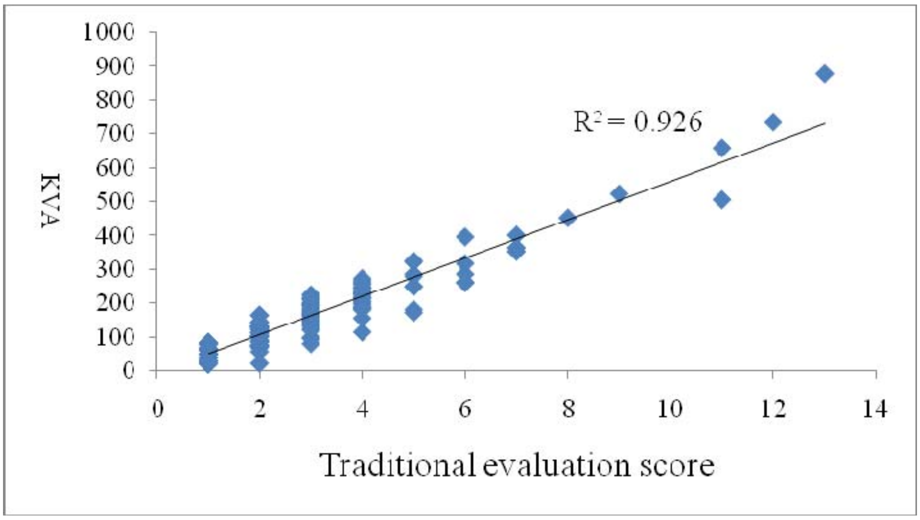

Figure 8 Example of regression testing—Supervision Art CoP

Discussions

In this section, several important issues related to the proposed KVAM and KVAS are discussed, including the application scenarios and system limitations.

Application scenarios

Use case I—performance evaluation of a specific CoP/individual

Based on the performance information provided by KVAS, the firm's KM manager is able to determine high and low performance CoPs or departments. Causes can be investigated to remove the obstacles of high performance. Similarly, the CoP's KM manager can monitor the high and low performance individuals chronically. An interesting fact was identified that individuals tend to participate KM activities enthusiastically before the annual performance evaluation season in order to "make up" the required credits; however, the average KVA of those make-up participations tend to be low. Moreover, the KVA profile provides information on high value-adding patterns that are related to the firm's incentive program. A sample system interface for Indivudal KM performance monitoring is shown in Figure 9.

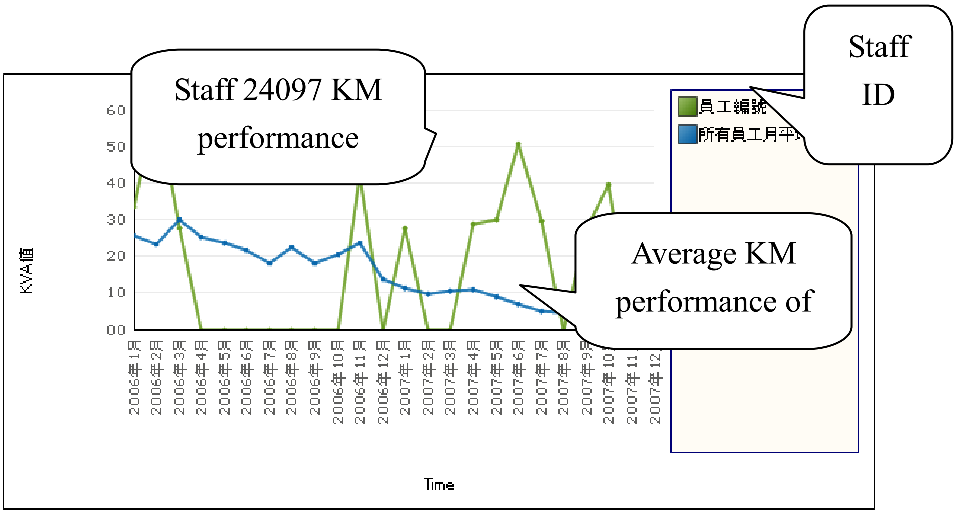

Figure 9 Indivudal KM performance monitoring

Use case II—quality analysis of KM activities

A second application of the proposed KVAS is to evaluate the quality of KM activities based on KVA. Traditional manual evaluation approach could not evaluate the quality of individual KM activity. The proposed KVAS provides analysis functions for CoP or department managers to visualize the quality of KM activities participated by a specific staff in a period of time. Figure 10 shows an example of the KM activity quality of a specific staff, in which the majority for both RKCP activities and the KVAP activities associated with the staff were categorized as "information" and "get" respectively. It means that the quality of the raw knowledge created by the staff was fair, but the values generated by the others to the raw knowledge were relatively low. As a result, the staff needs to improve the quality of KM activities he/she contributes.

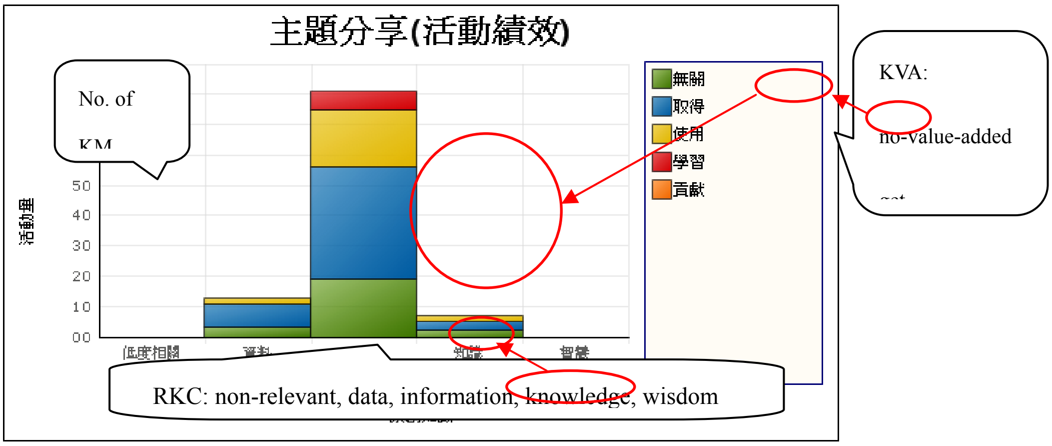

Figure 10 Quality analysis of KM activities

Use case III—improvement strategy planning

Another application of KVAS is to plan improvement strategies for the KM initiatived of the firm. In order to do so, advanced data mining techniques are applied to generate pattern and rules for decision-making [20]. As a result, the proposed KVAM and KVAS can be employed to plan the firm's KM strategies, and hopefully enhance the long term competitiveness of the firm.

Assumptions and limitations

Normalization of KVA values

The proposed KVAS assume that the average KVA values of each CoP to be "50", and force the lower and upper bounds of RKCP and KVAP scores to be within [5, 95] in order to allow extreme values in the future. Such an assumption may not be true, since a better-performed CoP should has an average KVA value than a poorer-performed CoP. This assumption may result in incorrect performance comparisons among different CoPs.

This critique is true for all index-based, rather than absolute value-based, measurement systems (e.g., BSC, KPI, etc.) in the short term. This problem may not be so severe as the system is operating for a long term when a long-term norm of the organization's average KVA value is established. Moreover, the CoP's short term KM performance can be determined by comparing the average KVA value of this term with that of previous term.

Limitation of the proposed KVAS

One major limitation of the proposed KVAS is that it only provides relative measures of KM performance rather than absolute values generated by a KMS. The absolute value-based measurement system is always related to the financial metrics as discussed in the literature review of this paper. However, the financial performance is usually influenced by some other factors beyond KM issues. It is impossible to single out the contribution of KM endeavour to financial revenue. A quantitative model proposed by Yu et al. [2] for measuring the time, man-hour, and cost saving resulted by a KMS may provide a solution. However, the abovementioned model is suitable only for emergent problem-solving activities. The KM activities of a generic CoP may not result in significant time and man-hour saving (and thus cost saving), but will trigger a knowledge creation process that may contribute to solving problems in the future. The essential solution to this problem is establishment of a relationship between KVA value and its monetary value. This can be future direction after this research.

Conclusion and Future Work

Conclusion

The paper presents a methodology to measure the KM performance of a generic CoP. A Knowledge Value Adding Model (KVAM) is proposed and developed to quantify the value generated by two types, knowledge sharing and problem solving, KM activities in a CoP. The proposed KVAM consists of two value adding stages: raw knowledge creation process and knowledge value adding process. Theoretical model of KVAM are developed and described. The fuzzy arithmetic approach is adopted to assist the quantification of KVA values in CoP. A case study of KVAM application is conducted. A web service system (called KVAS) is developed to implement KVAM. The KM performance measured by the proposed KVAS is then verified with the performance data obtained from traditional approach. The testing results indicate that the proposed KVAS is in conformance with the traditional KM performance evaluation method, but it provides more information to the firm's and CoP's KM managers so that the overall performance of the KMS is improved. Assumptions and limitations of the proposed method are also addressed to validate the applicability of the proposed system. It is concluded that the proposed KVAM is useful to quantify the performance of KM activities by calculating values generated in the KVA process. With the quantitative performance information, better KM performance improvement strategies can be developed.

Future work

The research has developed a method for quantitative evaluation of KM performance of a generic

CoP in a KMS. The data mining technique can be adopted to identify the patterns of high performance KM activities, so that the performance improvement strategies can be planned in the future. The other direction after this research is to relate the quantitative performance with monetary value that is more informative to the top managers.

Acknowledgement

The founding of this research project was partially supported by the National Science Council, Taiwan, under project No. 96-2221-E-216-054. Sincere appreciations are given to the sponsor by the authors. The valuable case study information presented in this paper was provided by CECI Engineering Consultants, Inc., Taipei. The authors would like to express sincere appreciations to the CECI, too.

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八、附錄—本研究已發表之著作表列

1. Yu, W. D., Chang, P.L. and Liu, S.J., "Quantifying Benefits of Knowledge Management System: A Case Study of an Engineering Consulting Firm," *Proceedings of International Symposium on Automation and Robotics in Construction 2006 (ISARC 2006)*, Session A4—Planning and Management (1), Oct. 3~5, 2006, Tokyo, Japan, pp. 124~129, 2006.
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行政院國家科學委員會補助團隊赴國外出差或研習心得報告

97 年 9 月 10 日

報告人姓名	余文德	服務機構	中華大學 建設系	職稱	教授
研習活動名稱	中文：第六屆國際工程計算科技研討會研習活動				
	英文：The Sixth International Conference on Engineering Computational Technology (ECT 2008)				
研習時間	2008/9/2~2008/9/5	地點(國、州、城市)	歐洲/希臘/雅典		

報告內容應包括下列各項：

一、參加研習經過

96/8/27：由於國內航空公司並無飛希臘之班機，因此，此次出國改搭泰國航空赴希臘。為爭取一些時間多參觀並瞭解國外之文化風情以增廣見聞，本次參加研討會提早於 8/27 出國，從桃園搭搭乘 TG635 班機轉 TG946 飛雅典。

96/9/28~9/1：此三天利用研討會前之時間，在雅典市區、附近 Mykonos 及 Santorini 等鄰近名勝參觀訪問，瞭解這個西方文明發源地以及歐洲觀光業最發達的國家之一如何發展與經營其文化及觀光產業。本人對於雅典市區經過 2004 年奧運建設後的進步狀況印象深刻，尤其是市容整潔、明亮，Mykonos 及 Santorini 等觀光區能在幾乎是不毛之地的條件下，發展成為吸引全世界觀光客的熱門觀光地點，實在值得正在大力發展觀光業的台灣借鏡與學習。

96/9/2~9/4：9/2 參加於於希臘首都雅典市洲際(Inter Continental)飯店所舉行之 ECT 2008 研討會。本研討會與另一個研討會「國際計算結構科技研討會(CST 2008)」合併舉行，因此共有超過三百人參與，是個規模龐大的研討會。9/2 為研討會開幕式，由英國愛丁堡 Heriot-Watt University 的 Professor B. H.V. Topping 及國立雅典科技大學 Professor M. Papadrakakis 共同主持。隨後並邀請美國德州大學奧斯汀分校 Professor T. J.R. Huges 主講 “Computational and Applied Mathematics”。 9/3 本人參與論文發表並負責主持場次討論。9/4 仍有多場論文發表場次進行，大多在 CST 2008 部分之計算流體與計算結構方面。有關工程管理相關部分有 “Computational Modelling, Analysis & Simulation”、 “GAs and NNs in Engineering”及 “Soft Computing”等領域。由於趕搭 9/4 當天班機回國，因此我們並未參加最後一天(9/5)的研討會。但在參加研討會期間，本也利用 Coffee break 及 lunch 時間與來參加研討會的各國學者交流，建立不少友誼。

圖一：主持論文發表場次

圖二：會場留影

圖三：發表論文

96/9/5：搭 TG947 轉 TG634 自雅典返回桃園機場，結束此次長途旅程。

二、研習心得

本人此次原本負責主持之場次是在9/3上午11:00~12:30的 “Decision making in engineering management”，然而由於該場次前一時段(9:00~10:30)之主持人無法主持，故本人臨時增加前一時段之場次主持工作。而本人所發表的論文則在第二時段，共發表兩篇論文：(ECT-31) “Construction Technological Strategy Planning Based on Patent Analysis”及(ECT-34) “Knowledge Value Adding Model for Quantitative Performance Evaluation of the Community of Practice in a Consulting Firm”。前者是本人與前指導博士班學生羅紹松所共同研究之結果，主要在運用專利資料庫之知識來作為營建工發創新規劃之基礎。此一方法與傳統以專家之勢為基礎之營建技術策略規劃方法不同，改以客觀且龐大的專利資料庫作為知識來源，且以技術領域為範圍，針對某特定工法技術之專利資訊進行分析。這可改進過去不分技術領域的技術策略規劃可能無法反應最新技術發展現況，且可能 induce 專家主觀之偏見的缺點，因此是一個創新的作法。後者則是本人所領導之研究團隊長期結合國科會研究計畫並與國內第一大工程顧問業(中華顧問工程司)之合作研究成果，主要在針對顧問業知識管理系統之知識社群的績效進行量化評估。知識管理績效量化評估是產業界長期所面臨的難題，因為知識是無形的其效益也常常是無形的，如何將組織的知識管理績效作有效評估是知識型產業(例如工程顧問業)所當務之急。於本研究中本人提出一種新的分析模式(稱為 KVAM)來分析知識社群中之知識加值活動，並結合模糊理論，發展出一套量化分析方法，以有效地評估組織中成員所進行的知識管理活動價值，解決了產業界長久以來的困境。完成兩篇論文發表後，分別接受幾個與會者的提問，不過提問者最有興趣的部分是「知識來源」，亦即模糊法則如何訂定，以及模糊運算如何進行。很顯然大家對於知識管理以及專利分析都不熟悉，更遑論將其應用於營建產業之問題解決上。本研討會仍有多場論文發表場次進行，大多在 CST 2008 部分之計算流體與計算結構方面。有關工程管理相關部分有 “Computational Modelling, Analysis & Simulation”、 “GAs and NNs in Engineering”及 “Soft Computing”等領域。由於趕搭 9/4 當天班機回國，因此我們並未參加最後一天(9/5)的研討會。但在參加研討會期間，本也利用 Coffee break 及 lunch 時間與來參加研討會的各國學者交流，建立不少友誼。

三、其他考察參觀活動（無是項活動者省略）

此次趁參與研討會之便順便參訪了希臘附近離島觀光地區，發現希臘雖位於地中海，然其幾個著名的觀光離島卻是不折不扣的不毛之地，可以想見在古代這些離島應是像馬祖、東引等難以耕種生產的荒島。然而希臘政府在於廿世紀初開始投入心力，善用其位於歐洲南方及每年四到九月陽光普照的優勢，將其發展成為世界聞名的觀光勝地。看看別人，想想自己，深深覺得台灣要發展觀光的資源與本錢並不希臘差。希臘有歐洲，台灣有中國大陸；希臘有歷史古蹟(但並不多)，台灣有美食與因戰爭而融合的中國文化。所不同的是希臘國民的文化素養、語文能力及生活素質似乎高於國人。因此，台灣要發展成為世界及的觀光勝地，首要工作在於提升國民的文化與生活素養。

四、建議事項

ECT 為「國際土木計算營(Civil Camp)」所 organize 的一個研討會，而 Civil Camp 之發起人 Prof. Topping 則是英國 Heriot-Watt University 教授。該組織長期透過舉辦國際性大型學術研討會而享有聲譽，期中最重要的有 CST 及 ECT 兩大系列，皆是以計算機於工程應用為主要領域，但也接受其他工程相關領域(如營建管理等)之投稿。本次營管相關論文主要集中在 “Decision making in engineering management”及 “Computational Modelling, Analysis & Simulation”等兩個場次，研究主題仍在計算理論及資訊技術之應用等，有關模式建構與創新則較少。由此次參與之經驗發現，工程問題解決之創新模式可以是未來發展的研究領域，特別是傳統困難管理問題的創新解決方法是國外學者較少碰觸的課題，也將是吾人可以突出的領域。

五、其他

攜回資料名稱及內容

1. 大會論文書面資料（ECT 2008 Proceedings）。
2. 大會光碟資料。
3. “Trends in Engineering Computational Technology”專書一冊。