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Construction of key model for knowledge management system using AHP-QFD for semiconductor industry in Taiwan

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Abstract

Purpose – The purpose of this paper is to describe the construction of a key model for knowledge management (KM) systems using AHP-QFD for the semiconductor industry in Taiwan.

Design/methodology/approach – The performance evaluation matrix was modified to set up a standard performance matrix for system introduction. The importance weights of models related to KM via the analytic hierarchy process (AHP) and after consulting experts' opinions. The method of quality function deployment (QFD) was integrated for the system models of a KM system and correlation weights of key objectives to be improved.

Findings – Seven key objectives need to be improved. Correlations between the key objectives to be improved and the KM system models are located via QFD for eight critically important models to be improved.

Research limitations/implications – In this study, the questionnaires were e-mailed to respondents sampled from the list of the Taiwan Semiconductor Industry Association (TSIA).

Practical implications – Actual cases are investigated and a KM system prototype is established in this research to provide reference for the semiconductor industry when introducing a KM system.

Originality/value – Companies can evaluate the performance of system introduction rapidly and regulate their investments in resources efficiently using the measurement, analysis and improvement methods provided here so that the performance of introducing the KM system will be increased effectively at the lowest cost.

Keywords Knowledge management, Analytical hierarchy process, Quality function deployment, Semiconductors, Taiwan

Paper type Research paper

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1. Introduction

Many organizations are increasingly viewed as knowledge-based enterprises in which formal knowledge management (KM) is essential (Wong and Aspinwall, 2005). Nowadays, KM is rapidly becoming an integral business activity for organizations as they realize that competitiveness pivots around the effective management of knowledge (Grover and Davenport, 2001). The USA, global leader in economy, has been skyrocketing throughout the past decade. The main reason is their grasp of knowledge, research and development and innovation. Consequently, they grow fast in various knowledge-based industries. According to the International Data Center (IDC, 2002), the market scale of KM consultancy leaped from US $ 1.1 billion in 1998 to US $ 3.4 billion in 2002, indicating that KM has become an important star industry in USA.

Today, organizations are living in a world if expanding knowledge, most people being knowledge workers, and knowledge being the only true business asset. Global organizations have started using KM technologies to heighten their competitiveness KM has become recognized as a significant source of competitive advantage (Nonaka, 1991; Nonoka and Takeuchi, 1995; Davis, 1998; Matusik and Hill, 1998; Miller, 1999; Almashari *et al.*, 2002).

Different from labor and capital, knowledge is intangible and hard to quantify. Being a burgeoning field, KM is bound to face challenges and difficulties. One of the key concerns that emerge in KM is how to accomplish it. Many companies that are attempting to initiate KM are unsure of the best approach to adopt (Moffett *et al.*, 2002). According to the analysis in Davenport (1996) the most difficult problems include the following:

- What are the future and the trend for KM? They are probably hard to understand, control and further specify even for the experts.
- Every business needs to select one KM model suitable for development of respective business; however, no related strategies have been specified because the key objectives to implementing KM in a business remain unclear.
- How to make good use of KM to enhance the competitiveness of a business efficiently?

After 40 years of development, the semiconductor has become an essential key component part for various electronic and information products, which are closely related to our daily lives. Electronic related products will continue growing in the future due to development of the information network, e-commerce and mobile communication. Therefore, semiconductor, the core of these products, will continue to play a critically important role. Though the semiconductor industry in Taiwan, a key star industry in the process of economic development, has a certain scale and advantages; keen competitions and challenges from big enterprises are still encountered. In addition to product competition, “knowledge” is also another arena. The only way to enhance the overall competitive advantages for an enterprise is to strengthen KM of internal personnel. As a result, introduction of the KM information system will be a key element in the semiconductor industry. In view of the above, performance evaluation analysis of introducing KM to the semiconductor industry in Taiwan will be conducted to locate factors with bad performance.

Moreover, application of information technology to improve these factors with bad performance will also be studied.

2. Definition and evaluation of knowledge management performance

2.1 The performance evaluation matrix

Hung *et al.* (2003) modified the performance evaluation matrix proposed by Lambert and Sharma (1990) and used two performance indices, Easiness (E) and Importance (I), to evaluate the performance of KM implementation factors. Easiness and importance of factors of implementing a KM system vary with the amount and distribution of material and human resources in a company. Generally speaking, greater investment in resources results in greater easiness when introducing KM to a company and vice versa. Next, the ideas of Parasuraman *et al.* (1985, 1991) were considered, and a performance evaluation index is defined. Using the k scale to assess the easiness and importance for each implementation factor, we obtain the easiness and importance indices as:

$$P_{\mathrm{E}} = \frac{\mu_{\mathrm{E}} - \min}{R}. \quad (1)$$

$$P_{\mathrm{I}} = \frac{\mu_{\mathrm{I}} - \min}{R}. \quad (2)$$

P_{E}: Easiness index; P_{I}: Importance index μ_{E}: Easiness mean; μ_{I}: Importance mean min: the minimum value of k scale; R: the full range of k scale

μ_{E} and μ_{I} are the means of E and I, respectively. Moreover, $min = 1$ represents the minimum value of k scale and $R = k - 1$ is the full range of k scale. A lower value indicates that the easiness or importance of performing a particular factor is low. Obviously, these three indices are within zero and one. For example, for the scale of five ($k = 5$) with $R = k - 1 = 4$, when the average easiness or importance exceeds 3 (medium), the index value will be exceeding 0.5 (half) and the integral average easiness or importance will be positive. Meanwhile, when the average easiness or importance is below 3 (medium), the index value will be below 0.5 (half) and the integral average easiness or importance will be negative. Consequently, positive or negative evaluation of an enterprise towards each KM implementation factor can be examined using the index values by providing a convenient and efficient management tool to evaluate the performance of introducing a KM system. The index of importance is plotted as a Y-coordinate and that of easiness as the X-coordinate. A performance matrix is redefined according to various strategic requirements for KM, as a tool for use in the performance analysis and improvement of a newly introduced system. Hung *et al.* (2003) have adjusted the performance evaluation matrix by applying more than two indices to the performance matrix. Taking the index of importance as the Y-coordinate and that of easiness as the X-coordinate, we find that all index values are within zero and one. Four criteria [0.0, 1/3, 2/3, 1.0] were adopted, and three performance levels were formed; i.e. the least easiness of [0.0, 1/3], medium easiness of [1/3, 2/3], and greatest easiness of [2/3, 1.0]. The importance levels can also be divided into three levels, namely the least importance, medium importance, and the greatest importance levels. The matrix can be expressed by the notion of B_{ij} (where i and j are 1, 2, and 3) using nine performance zones to represent different types of performance levels. Thus, the management can employ strategies to define the "target zone" by focusing on an appropriate performance level, i.e. B_{11}, B_{22}, and B_{33}, where easiness is equal to importance ($i = j$). When importance is higher than easiness ($i > j$), B_{12}, B_{13}, and B_{23} are located, meaning that the resources should be increased to enhance the system performance. When importance is lower than easiness ($i < j$), B_{31}, B_{32}, and B_{21} are located, indicating that the resources should be decreased to reduce the cost of system introduction. Accordingly, the integral easiness index of integrating importance and easiness indices can be expressed as follows:

$$P_{I-\mathrm{E}} = P_I - P_\mathrm{E} \tag{3}$$

$P_{I-\mathrm{E}}$ represents the integral easiness index value, P_E is the easiness index and P_I is the importance index. When an enterprise improves the performance level of introducing a KM system to bring it within the target zone, in accordance with the arrow direction in Figure 1, the easiness and importance for each implementation factor will be close. As a result, it is more possible to achieve the appropriate performance level. Improvement strategies and suggestions for each performance zone can be divided into increasing resources to strengthen easiness, reducing resources to cut system introduction cost and maintenance of the status quo. The management can evaluate the performance level for each implementation factor and devise improvement strategies according to the locations of the easiness and importance indices in a performance matrix. The performance matrix is found to be a simple and easy-to-use graphic analysis tool for enterprise management and helpful for monitoring the performance evaluation of KM system introduction.

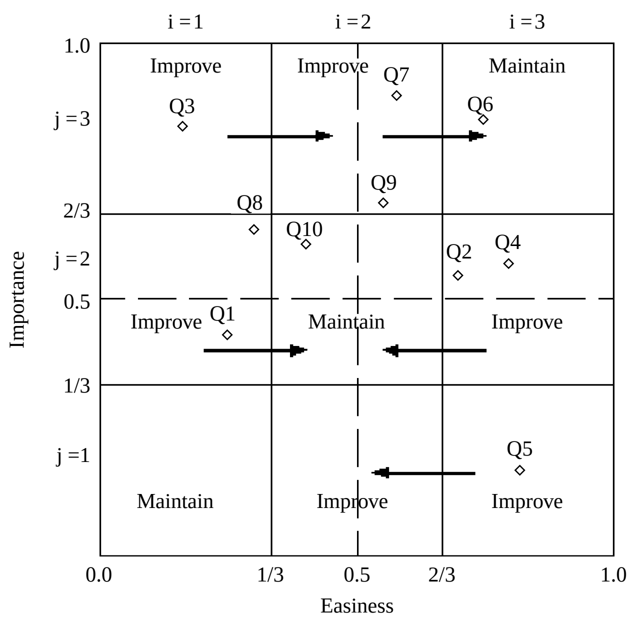

Figure 1.
Appropriate performance zones

2.2 The performance evaluation matrix for knowledge management

Before specifying the implementation factors of a KM system, a KM system has to be defined first. KM means to manage all knowledge continuously to meet various requirements in an organization (Qunitas *et al.*, 1997). Coleman (1999) defines KM as an umbrella term for a wide variety of interdependent and interlocking functions consisting of: knowledge creation; knowledge valuation and metrics; knowledge mapping and indexing; knowledge transport, storage and distribution; and knowledge sharing. Gurteen (1998) comprehensively defined KM as:

> . . . an emerging set of organizational design and operational principles, processes, organizational structures, applications and technologies that helps knowledge workers dramatically leverage their creativity and ability to deliver business value.

Three types of intellectual capital, human, organizational and customer capital, can be shared, motivated and fostered for better performance (Petrash, 1996) via activities like knowledge identifying, capturing, selecting, storing, sharing, applying and creating (Beckman, 1997). Four major dimensions for the process of KM activities presented by Nonoka and Takeuchi (1995) and Davenport and Prusak (1998) were adopted for the general model structure of KM in enterprises. These four dimensions are knowledge creation, knowledge diffusion, knowledge transfer and knowledge inventory. Evaluation indices screened from these dimensions will be utilized to build a performance evaluation model having a hierarchical structure for KM in a business shown in Figure 2.

To measure KM implementation factors, members of the Taiwan Semiconductor Industry Association (TSIA, 2004) were taken as the object of study. People in charge of KM-related practice were invited to be respondents of our questionnaire survey. Directors responsible for KM-related practice defined here refer to chiefs in the KM department,

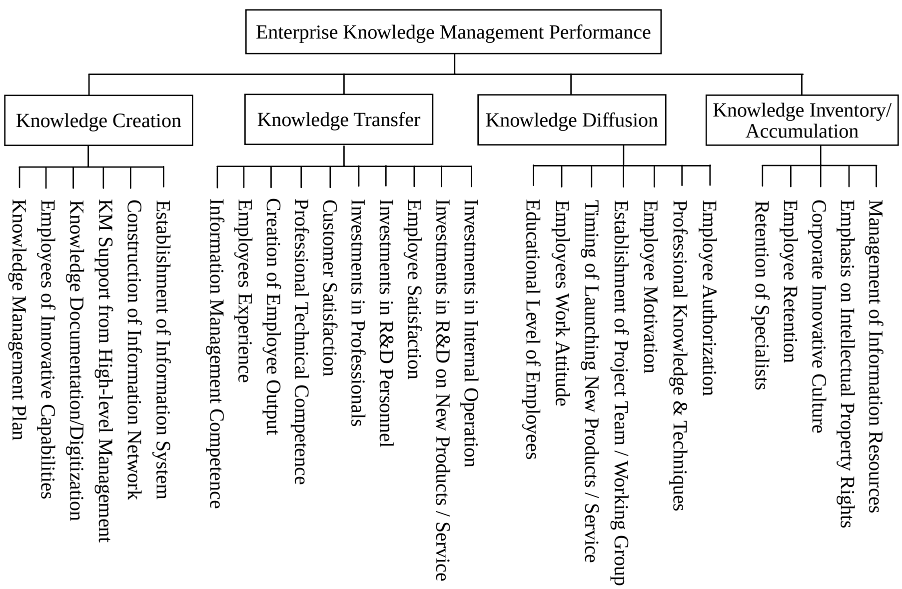

Figure 2.
Knowledge management performance evaluation factors

the human resources department and the information department as well as general managers and vice general managers. The main purpose of the survey is to investigate the importance and easiness of each implementation factor when the semiconductor-related industries in Taiwan introduce the KM system. Likert's five-point scale was employed. For easiness, the five levels were divided into very easy, easy, medium, not easy and very difficult. A score of five points is given to very easy and that of 1 point is given to very difficult. The five levels of importance were also divided into very important, important, medium, unimportant and very unimportant. A score of five points is given to very important and that of 1 point is given to very unimportant. In this study, a total of 192 questionnaires were e-mailed to respondents sampled from the list of the TSIA (2004), and 45 questionnaires were returned and three of which were invalid. That is, there were 41 effective returned questionnaires, representing a feedback percentage of 21.3 percent. Consistency, accuracy and reliability of the questionnaire on KM performance were judged by Cronbach's α. In principle, a greater Cronbach's α represents higher reliability of the questionnaire. A reliability coefficient above 0.7 was highly reliable and that between 0.35 and 0.7 was acceptable; however, a coefficient below 0.35 was lowly reliable and should be rejected, according to Guieford (1965). As the overall reliability of this questionnaire was 0.8545, the reliability coefficient was quite high-indicating consistent and reliable results of the questionnaire. Computations of the means and index values of easiness and importance are listed in Table I.

1σ standard deviation of $P_{I-\mathrm{E}}$ in the performance matrix in Figure 3 is 0.085492659. As the target value is 0, the upper and lower control lines may be defined as 2σ, that lies between 0.17 and $-$ 017. When an overall easiness index value P_{I-E} is higher than 0.17, it is called an abnormal implementation factor. There are seven abnormal factors in this case and they are: Timing of Launching New Products/Service in K3, KM Plan in I1, Management of Information Resources in L5, Information Management Competence in J1, Employees Work Attitude in K2, Corporate Innovative Culture in L3, and Employees of Innovative Capabilities in I2. Since, they have bad overall easiness, they are listed as "key objectives" to be improved. Next, improvement alternatives will be presented by information technology.

3. Measurement of knowledge management system models

All the KM system models cannot be introduced at one time. Consequently, the analytic hierarchy process (AHP) was adopted to locate the importance weight of each model in the KM information system. Priority of models to be introduced will be determined by the correlations between the importance weight of each model and the key implementation factors.

3.1 The analytic hierarchy process method

The AHP was developed by Saaty (1977), a professor of University of Pittsburgh. AHP is a multi-objective decision-making (MODM) method using the organizational structure to establish an interactive hierarchical structure. AHP is becoming popular with academic researchers for data analysis, model verifications to provide critical information for managers to make business decisions. This decision-making approach is mainly applied to decision problems with several evaluation norms under uncertain circumstances (Chung *et al.*, 2005).

Table I.
Table of knowledge management performance evaluation statistics

	Evaluation index	Importance μ_I	Easiness μ_E	Importance P_I	Easiness P_E	P_{I-E}	Remarks
Knowledge creation I	I1. Knowledge management plan	4.10	2.97	0.78	0.49	0.29	2[a]
	I2. Employees of innovative capabilities	3.46	2.80	0.62	0.45	0.17	7[a]
	I3. Knowledge documentation/digitization	4.00	3.68	0.75	0.67	0.08	
	I4. KM support from high-level management	4.14	3.68	0.79	0.67	0.12	
	I5. Construction of information network	3.75	3.75	0.69	0.69	0	
	I6. Establishment of information system	3.75	3.79	0.69	0.70	−0.01	
Knowledge transfer J	J1. Information management competence	3.86	2.95	0.72	0.49	0.23	4[a]
	J2. Employees experience	3.61	3.43	0.65	0.61	0.04	
	J3. Creation of employee output	3.57	3.25	0.64	0.56	0.08	
	J4. Professional technical competence	3.79	3.50	0.70	0.63	0.07	
	J5. Customer satisfaction	3.86	3.61	0.72	0.65	0.07	
	J6. Investments in professionals	3.71	3.39	0.68	0.60	0.08	
	J7. Investments in R&D personnel	3.86	3.75	0.72	0.69	0.03	
	J8. Employee satisfaction	3.71	3.43	0.68	0.61	0.07	
	J9. Investments in R&D on new products/service	3.89	3.64	0.72	0.66	0.06	
	J10. Investments in internal operation	3.89	3.64	0.72	0.66	0.06	
Knowledge diffusion K	K1. Educational level of employees	3.64	3.20	0.66	0.55	0.11	
	K2. Employees work attitude	3.61	2.80	0.65	0.45	0.2	5[a]
	K3. Timing of launching new products/service	4.04	2.70	0.76	0.43	0.33	1[a]
	K4. Establishment of project team/working group	3.75	3.43	0.69	0.61	0.08	
	K5. Employee motivation	3.54	3.50	0.64	0.63	0.01	
	K6. Professional knowledge & techniques	3.68	3.54	0.67	0.64	0.03	
	K7. Employee authorization	3.89	3.64	0.72	0.66	0.06	
Knowledge inventory/ accumulation L	L1. Retention of specialists	3.68	3.39	0.67	0.60	0.07	
	L2. Employee retention	3.64	3.43	0.66	0.61	0.05	
	L3. Corporate innovative culture	3.36	2.6	0.59	0.40	0.19	6[a]
	L4. Emphasis on intellectual property rights	3.64	3.25	0.66	0.56	0.1	
	L5. Management of information resources	3.86	2.92	0.72	0.48	0.24	3[a]

Note: [a]Refers to factors having a total performance value, P_{I-E}, higher than 0.17, the upper control line or lower than −0.17, the lower control line

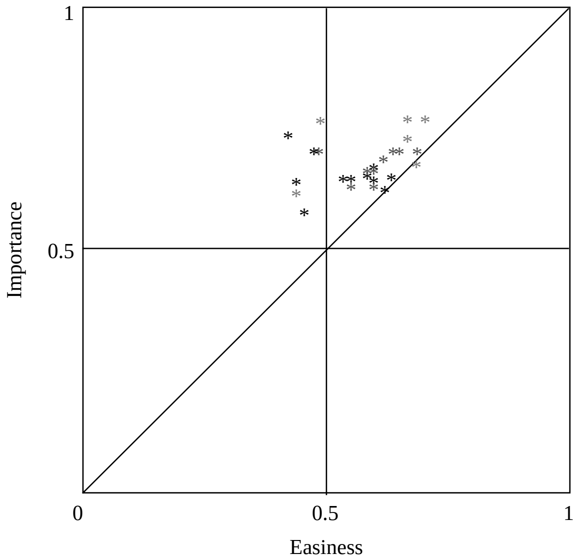

Figure 3.
Performance matrix of importance vs easiness

AHP has been widely employed in decision-making analysis in various fields such as political, social, economic and management sciences. AHP combines both qualitative and quantitative approaches (Cheng *et al.*, 2002). In the qualitative sense, it decomposes an unstructured problem into a systematic decision hierarchy. It then uses a quantitative way to employ pair-wise comparison to determine the local and global priority weights and the overall ranking of the alternatives.

3.2 AHP for knowledge management system

The flow of applying the AHP to the case here is described as shown in the following sub sections.

3.2.1 Identify decision problems. Problems need to be clarified first for definition and purpose of decision-making. Problems should be known well when applying the AHP to stratification of elements to be evaluated in particular.

3.2.2 List every evaluation element. Opinions of experts and decision-makers should be integrated prior to listing each evaluation factor. Order and correlation of decision factors need not be considered at this time. The correlation model of the KM information system proposed by Sarvary (1999) and Bollinger and Smith (2001) was adopted here.

3.2.3 Set up hierarchical relationship. Evaluation elements are stratified in accordance with correlations and independence. Stratification will depend on the complexity of the problem for analysis; however, elements of each tier should be limited to nine to prevent conflicts affecting evaluation results and the factors of each tier need to be independent. The hierarchical structure is formed by the overall objectives, subtargets and final decisions. The number of tiers is determined by the complexity and level of analysis of the decision. Accordingly, the models related to KM information system can be divided into four major types, which are knowledge collaboration, e-learning, document management and decision support. Fifteen models are further divided as the basis of models related to the KM information system as shown in Table II.

1	Models related to knowledge management information system														
2	Collaboration				E-learning				Document management				Decision support		
3	M1: real-time communication/ video conference	M2: e-mail	M3: complete calendar	M4: project process control follow-up	M5: bulletin board system (BBS)	M6: e-learning system	M7: discussion forum	M8: e-paper	M9: document database	M1: full-text retrieval system (indexing service)	M11: documents verification system	M12: journal	M13: data mining	M14: decision support system	M15: expert system

Table II.
Hierarchy of Models Related to Knowledge Management Information System

3.2.4 Pair-wise comparison. Upon establishing the hierarchical structure, a questionnaire may be designed or relative importance between evaluation factors of the same level can be assessed by experts. Elements of the previous tier form the basis for rating in the AHP method; i.e. significance or influence of any two elements of the same tier are compared with that in the previous tier so that the burden of the decision maker can be relieved and relativity of decision factors may be manifested clearly. A nominal scale is adopted for the evaluation indices in a paired comparison in the AHP and nine scales are divided as shown in Table III. Next, the questionnaire was sent to 11 advisors, experts and scholars assisting enterprises in introducing the KM system and the directors of the KM department in the semiconductor industry. Paired matrices were set up using pair-wise comparison. Four dimensions of collaboration, e-learning, document management and decision support were on the second tier of the questionnaire as the norm of evaluating the importance of each model in the KM information system in addition to a comparison of relative significance of the following factors. Likewise, the same method was also applied to the third tier. About 11 experts responded to the questionnaire. Experts' objective assessments on the relative significance of each factor were obtained via the questionnaire survey.

3.2.5 Establish pair-wise comparison matrix. A pair-wise comparison matrix is established using the appraisal factors of each tier compared with n appraisal factors of the following tier for pair-wise comparison evaluation values. a_{ij}, the resultant $\mathrm{C}(n, 2) = n(n-1)/2$ evaluation values, is the element value of the main diagonal on the upper right quadrant of a pair-wise comparison matrix (as shown in Table IV).

Intensity of importance of an absolute scale	Definition	Description
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance of one over another	Experience and judgment strongly favor one activity over another
5	Essential or strong importance	Experience and judgment strongly favor one activity over another
7	Very strong importance	An activity is strongly favored and its dominance demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between the two adjacent judgments	When compromise is needed
Reciprocals	If activity *i* has one of the above numbers assigned to it when compared with activity *j*. then *j* has the reciprocal value when compared with *i*.	
Rationals	Ratios arising from the scale	If consistency were to be forced by obtaining *n* numerical value to span the matrix

Source: Saaty (1994)

Table III. The fundamental scales in AHP

The inverse of the element value on the upper right of the corresponding location is placed on the lower left of the main diagonal line and the element value on the main diagonal is set as 1 for a complete pair-wise comparison matrix A:

$$A = [a_{ij}] = \begin{array}{c c} & \begin{array}{cccc} A_1 & A_2 & \cdots & A_n \end{array} \\ \begin{array}{c} A_1 \\ A_2 \\ \vdots \\ A_n \end{array} & \begin{bmatrix} W_1/W_1 & W_1/W_2 & \cdots & W_1/W_n \\ W_2/W_1 & W_2/W_2 & \cdots & W_2/W_n \\ \vdots & \vdots & & \vdots \\ W_n/W_1 & W_n/W_2 & \cdots & W_n/W_n \end{bmatrix} \end{array}$$

where:

$$a_{ij} = \frac{W_i}{W_j}, \quad a_{ji} = \frac{1}{a_{ij}}, \quad W = \begin{bmatrix} W_1 \\ W_2 \\ \vdots \\ W_n \end{bmatrix}$$

Make $a_{ij} = W_i/W_j$ *and* $W_1, W_2, \cdots, W_n$ refer to the relative weights of each element corresponding to a certain element in the previous tier. There are two characteristics in this matrix as follows:

(1) The pair-wise comparison matrix by AHP is a transpose.

(2) If expert's evaluation is perfectly accurate, then the matrix is called a consistent matrix; indicating that all comparison values satisfy transitivity.

3.2.6 Calculate eigenvalue vector and maximized eigenvalue of each comparison matrix. After establishing pair-wise comparison matrices, the numerical analysis method is employed to calculate the eigenvalue vector and the maximized eigenvalue for an understanding of the consistency established and the relative weight among elements. The Normalization of the Geometric of the Rows (NGM) method is applied, which obtains a geometric mean by multiplying elements of each row for normalization:

Table IV. The first expert's answer on a two-tier questionnaire

Appraisal factor	Collaboration	E-learning	Document management	Decision support
Collaboration	1	3	2	2
E-learning	1/3	1	2	1
Document management	1/2	1/2	1	4
Decision support	1/2	1	1/4	1

$$\begin{bmatrix} 1 & 3 & 2 & 2 \\ 1/3 & 1 & 2 & 1 \\ 1/2 & 1/2 & 1 & 4 \\ 1/2 & 1 & 1/4 & 1 \end{bmatrix} \rightarrow \begin{bmatrix} \sqrt[4]{12} \\ \sqrt[4]{0.66} \\ \sqrt[4]{1} \\ \sqrt[4]{0.125} \end{bmatrix} \rightarrow \begin{bmatrix} 1.86/4.35 \\ 0.90/4.35 \\ 1/4.35 \\ 0.59/4.35 \end{bmatrix} \rightarrow \begin{bmatrix} 0.427 \\ 0.206 \\ 0.229 \\ 0.135 \end{bmatrix}$$

Eigenvalue vector:

$$\begin{bmatrix} 1 & A_{12} & \cdots & A_{1n} \\ 1/A_{12} & 1 & \cdots & A_{2n} \\ \vdots & & \ddots & \vdots \\ 1/A_{1n} & 1/A_{2n} & \cdots & 1 \end{bmatrix} \bullet \begin{bmatrix} W_1 \\ W_2 \\ \vdots \\ W_n \end{bmatrix} = \begin{bmatrix} W'_1 \\ W'_2 \\ \vdots \\ W'_n \end{bmatrix} \quad (4)$$

$$\lambda_{\max} = \frac{1}{n}\left(\frac{W'_1}{W_1} + \frac{W'_2}{W_2} + \cdots + \frac{W'_n}{W_n}\right)$$

Standardization of vectors and inverses of rows: Sum up the elements of each row and calculate their inverses for normalization. In practice, the eigenvalue vector is obtained by the first three methods and the third one, the NGM approach, is the most common.

Maximized Eigenvalue, $\lambda_{\max}$, is described as follows:

First, compute the product of the pair-wise comparison matrix A and the eigenvalue vector for a new vector, W'. Then, each vector value of W' is divided by the corresponding vector value in W. Finally, add all the obtained values and calculate their mean (by dividing with order number n). $\lambda_{\max}$ can thus be calculated as:

$$\because A \bullet W = \begin{bmatrix} 1 & 3 & 2 & 2 \\ 1/3 & 1 & 2 & 1 \\ 1/2 & 1/2 & 1 & 4 \\ 1/2 & 1 & 1/4 & 1 \end{bmatrix} \cdot \begin{bmatrix} 0.427 \\ 0.206 \\ 0.229 \\ 0.135 \end{bmatrix} = \begin{bmatrix} 1.773 \\ 0.941 \\ 1.085 \\ 0.611 \end{bmatrix} \quad (5)$$

$$\therefore \lambda_{\max} = \frac{1}{n}\sum_{i=1}^{n}\frac{(AW)_i}{W_i} = \frac{1}{4}\left(\frac{1.773}{0.427} + \frac{0.941}{0.206} + \frac{1.085}{0.229} + \frac{0.611}{0.135}\right) = 4.496 \quad (6)$$

3.2.7 Consistency index (CI) and consistency ratio (CR). Consistency index (CI) and consistency ratio (CR) of pair-wise comparison matrices are calculated first. In practice, small a_{ij} variations result in small $\lambda_{\max}$ variations. Consequently, the difference between $\lambda_{\max}$ and n can be employed to measure the consistency of a matrix:

$$\mathrm{CI} = \frac{\lambda_{\max} - n}{n - 1}$$

Contrary to CI, the CI generated by a random inverse matrix is called the random index (RI), which increases as the order of the matrix increases. Next, the RI in Table V is utilized to obtain the CR:

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}}$$

In AHP, CR is employed to evaluate the overall consistency of pair-wise comparison matrices and a CR less than 0.1 is acceptable for consistency. If the CR is greater than 0.1, it means expert evaluation is random and re-evaluation or modification is required. Moreover, the CI generated randomly by a positive reciprocal matrix is called the RI. The RI corresponding to the order is calculated and listed in Table V as follows.

Take the case in this research as an example:

First, CI is calculated as $\mathrm{CI} = (\lambda_{\max} - n)/(n - 1) = (4.496 - 4)/(4 - 1) = 0.165$. Next, RI $= 0.90$. When $N = 4$ according to Table V. Finally, CR is computed as $\mathrm{CR} = CI/RI = 0.165/0.90 = 0.1833$.

When the CR is greater than 0.1, it implies that expert evaluation is random. Therefore, that questionnaire should be eliminated. Opinions of the other experts were also tested in the same manner. In the case presented here, the CR of one expert out of 11 was more than 0.1 and the questionnaire of the same expert was rejected. After averaging the evaluation scales of the remaining 10 experts, the eigenvalue vector was recalculated using the same procedures. As the process of computation is complicated, Expert Choice 2000 was used for entry of AHP questionnaires and calculation of weights. The evaluation indices in the third tier/layer are the continuation of those in the related models in the second tier/layer. For instance, there are five correlated models under collaboration, which are real-time communication/video conference in M1, e-mail in M2, complete calendar in M3, project process control follow-up in M4 and bulletin board system (BBS) in M5. Experts' opinions on these five related models under collaboration were obtained via a questionnaire survey and Expert Choice 2000 was used for pair-wise comparison matrices, as shown in Table VI.

Next, the weights of all elements under collaboration will be computed. Results and sorting of these weights are shown in Table VI.

3.2.8 Calculate the overall priority vector. When the consistency of the overall tiers/layers is acceptable, the last step in the AHP approach will be integrating the relative weights of elements of all tiers/layers for the overall priority vector. The computed vectors represent the priority of each decision alternative corresponding to its decision objective. Upon computation of tier weights of all evaluation standards, distribute the evaluation indices of related models in the third layer in proportion to the respective relative importance, which is the result of multiplying the weight of the previous tier and the relative weight of every element in this tier, indicating the significant role played by every element in this layer. The total weight of correlated models of all tiers will thus be generated. The computed weights will be obtained by entering the data of each tier into Export Choice 2000. The overall inconsistency is the CI (CI $= 0.10$) mentioned by Saaty (1980), which meets consistency testing.

Finally, the weights of all tiers are analyzed and arranged in Table VI.

Order	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.58

Note: Table of Random Indices of a Positive Reciprocal Matrix at n order

Table V.

Tier	AHP evaluation indices Evaluation index		Tier weight	Overall weight
1	Related models in knowledge management information system		1.000	1.000
2	Collaboration		0.441	0.441
2	E-learning		0.289	0.289
2	Document management		0.142	0.142
2	Decision support		0.127	0.127
3	Collaboration	M1: real-time communication/video conference	0.426	0.069
		M2: e-mail	0.200	0.147
		M3: complete calendar	0.178	0.026
		M4: project process control follow-up	0.119	0.041
		M5: bulletin board system (BBS)	0.077	0.062
3	E-learning	M6: e-learning system	0.622	0.015
		M7: discussion forum	0.247	0.073
		M8: e-paper	0.131	0.029
3	Document management	M9: document database	0.552	0.224
		M10: full-text retrieval system (indexing service)	0.271	0.110
		M11: documents verification system	0.100	0.041
		M12: journal	0.077	0.031
3	Decision support	M13: data mining	0.493	0.041
		M14: decision support system	0.311	0.065
		M15: expert system	0.196	0.026

Table VI. Table of Weights of Related Models in Knowledge Management Information System by AHP

4. Relationship between knowledge management system model and key objectives

After getting the importance weight of each model in the KM system by the AHP questionnaire and computation, the quality function deployment (QFD) method will be utilized to locate the correlations between models and key objectives for the key models in the KM information system.

4.1 The quality function deployment method

QFD was developed by Akao in 1972 and first systemized in Japan in the mid-1970s at Mitsubishi's Kobe shipyard (Akao, 1990). QFD can directly link the voice of customer to product planning and then to manufacturing. This input from the customer is vital in determining successful introduction of any new product (Rahim and Baksh, 2003). QFD can also be used systematically to evolve specifications of any system or product from a set requirement (Kumar and Midha, 2001). The QFD method has been used to capture requirements from customers and translate them into technical requirements (Rahim and Baksh, 2003). QFD in fact is a method of continuous product improvement, emphasizing the impact of organizational learning on innovation (Govers, 2001).

Wang (1999) suggested QFD planning as a multi-criteria decision problem and proposed a new fuzzy outranking approach to prioritize design requirements recognized in QFD, illustrating an example of a car design utilizing the proposed approach developed. Vanegas and Labib (2001) proposed a method for determining optimum targets in QFD.

While AHP is useful for analyzing multiple criteria in a structured hierarchal manner, it uses only relative priority values, not the actual performance, of specific tooling process.

QFD uses direct performance values, but cannot consider multi level criteria, unless a number of QFD charts are prepared, which is cumbersome (Hanumaiah *et al.*, 2006).

An integrated QFD-AHP approach has the advantages of both, and can be used in prioritizing customer requirements, enabling dealing with complex situations and order ranking (Fiorenzo, 2001). The QFD was successfully coupled with AHP for prioritization of customer requirements and also for establishing engineering relationships (Moisiadis, 2002). For example, Partovia and Epperly (1999) present a QFD-AHP model for determining the composition of a USA peacekeeping force deployed to Bosnia. Partovi and Corredoira (2002) present a QFD-AHP model for prioritizing and designing rule changes for the game of soccer in order to make it more attractive to soccer enthusiasts. Bhattacharya *et al.* (2005) integrated a model combining AHP and QFD for the industrial robot-selection problem. Hanumaiah *et al.* (2006) proposed QFD-AHP methodology is a new approach for the tooling process selection domain.

4.2 Summary of procedures

Procedures of the QFD method are described as follows:

(1) List customer's requirements (Whats) – what do the customers want? Define customer's requirements on the right of the house of quality (HOQ) as KM system models.

(2) List technical terms (Hows) – how to meet these requirements? Define the key objectives to be improved in the KM system as technical terms and list them on the top of the HOQ.

(3) Develop the relationship between customer's requirements (Whats) and their corresponding technical terms (Hows). Five experts decided the relations between customer's requirements and their corresponding technical terms jointly; i.e. the relationships between the models and the objectives to be improved in the KM system. According to the definition of correlation weights, a score of 5 points is given to an extremely strong positive correlation, 4 for a strong positive correlation, 3 for a medium positive correlation, 2 for a weak positive correlation and 1 for an extremely weak positive correlation.

(4) Correlation weights are calculated to determine the priority of customer's requirements. In Table VII, C_{ri} refers to the requirement of the i customer,

Table VII.
Quality function deployment table

			Design element (technical term) (objectives to be improved in KM system)			
		Weight of customer requirement (weight of models of knowledge management system)	D_{c1}	D_{cj}	D_{cn}	Objectives to be improved in KM system weights of KM system models & weights of customer requirement & design element
Customer requirement (models of KM system)	C_{r1}	W_{r1}	R_{11}	R_{1j}	R_{1n}	W_{d1}
	C_{ri}	W_{ri}	R_{i1}	R_{ij}	R_{in}	W_{di}
	C_{rm}	W_{rm}	R_{m1}	R_{mj}	R_{mn}	W_{dm}

D_{cj} means the j design element and R_{ij} represents the fulfillment of the requirement of the i customer (Cri) and the j design element (D_{cj}). Weights of the customer's requirements will be analyzed by the AHP. Weights of customer's requirements and design elements are computed as follows:

$$W_{di} = (R_{i1} \times W_{ri} + \ldots + R_{ij} \times W_{ri} + \ldots + R_{in} \times W_{ri}) \tag{7}$$

The weight of M_1 in this case is calculated using equation (7) as follows:

$$\begin{aligned} W_{d1} &= (R_{i1} \times W_{r1} + \ldots + R_{1j} \times W_{r1} + \ldots + R_{in} \times W_{r1}) \\ &= (4 \times 0.069 + 1 \times 0.069 + 2 \times 0.069 + 2 \times 0.069 + 4 \times 0.069 \\ &\quad + 3 \times 0.069 + 3 \times 0.069) = 1.31. \end{aligned}$$

Finally, results are listed in Table VIII. The first eight factors with the highest correlation weights are listed as key models for the construct of the KM system prototype. These key models include document database in M9, document database in M10, e-mail in M2, discussion forum in M7, real-time communication/video conference in M1, decision support system in M14, project process control follow-up in M4, and documents verification system in M11.

5. Selection of key models and establishment of system prototype

A great number of large-scale software application development manufacturers are competing in launching the so-called KM systems with one another to assist businesses in KM. The most well-known products are like Notes, a groupware from IBM, Microsoft Project Server and Microsoft Share Point Portal Server. Plenty of big enterprises even try to present their internal operation requirements in a KM manner such as HP, Oracle, P&G in Taiwan, the consulting industry and accountant firms. Consequently, AHP-QFD analysis was conducted on these related system models and cases for 50 percent important key models (eight models) at expert's decision as the models with top priority. Four major system dimensions from these models include Collaboration, e-learning, document management and decision support. Eight models are further divided under each function as shown in Figure 4. In this research, a portal site of KM system is developed using these models.

A developed KM system may provide eight models mentioned in this study like data mining, full-text retrieval system, personalized agent, discussion forum and document management by integrating various TCP/IP Servers (e.g. web server and mail server) and rear-end programming languages like ASP.NET of Microsoft Windows IIs Server and cross-platform Java language. The enterprise information portal in this research was developed using the.NET, Microsoft Windows Server Platform, Microsoft Sharepoint Portal 2003 and Microsoft SQL Server 2000. Microsoft Visual Studio and Microsoft Visual Studio.NET was employed to develop these eight models, which is highly integrated for office systems. Accordingly, the enterprise information portal developed in this paper is shown in Figure 5 as follows.

The KM portal site prototype in this research is established using the semiconductor industrial characteristics and eight selected sub-models. Windows

Table VIII.
QFD of Models vs Key Objectives in KM System

Knowledge management models	*Correlation weight* Definition of correlation weights: Extremely strong: 5 points Strong: 4 points Medium: 3 points Weak: 2 points Extremely weak: 1 point	KM model weights derived from AHP	Key objectives K3: timing of launching new products/service	I2: employees of innovative capabilities	K2: employees work attitude	L3: corporate innovative culture	L5: management of information resources	J1: Information management competence	I1: KM plan	Weight	Sorting
Collaboration	M1: real-time communication/video conference	0.069	4	1	2	2	4	3	3	1.31	5*
	M2: e-mail	0.147	4	1	2	1	3	3	4	2.65	3*
	M3: complete calendar	0.026	5	2	1	1	4	3	5	0.55	10*
	M4: project process control follow-up	0.041	5	1	3	1	3	4	5	0.90	7*
	M5: bulletin board system (BBS)	0.062	4	2	2	3	3	3	4	1.30	14
E-learning	M6: e-learning system	0.015	3	3	1	3	3	3	2	0.27	15
	M7: discussion forum	0.073	4	3	3	4	3	3	3	1.68	4*
	M8: e-paper	0.029	3	3	1	2	3	3	2	0.49	11
Document management	M9: document database	0.224	4	1	1	1	4	4	3	4.03	1*
	M10: full-text retrieval system (indexing service)	0.110	4	2	1	2	4	4	3	2.20	2*
	M11: documents verification system	0.041	4	4	1	2	3	3	2	0.78	8*
Decision support	M12: journal	0.031	3	2	1	1	3	3	2	0.47	12
	M13: data mining	0.041	5	2	1	1	3	2	3	0.70	9*
	M14: decision support system	0.065	3	3	2	2	3	3	2	1.17	6*
	M15: expert system	0.026	2	2	1	2	3	3	2	0.39	13

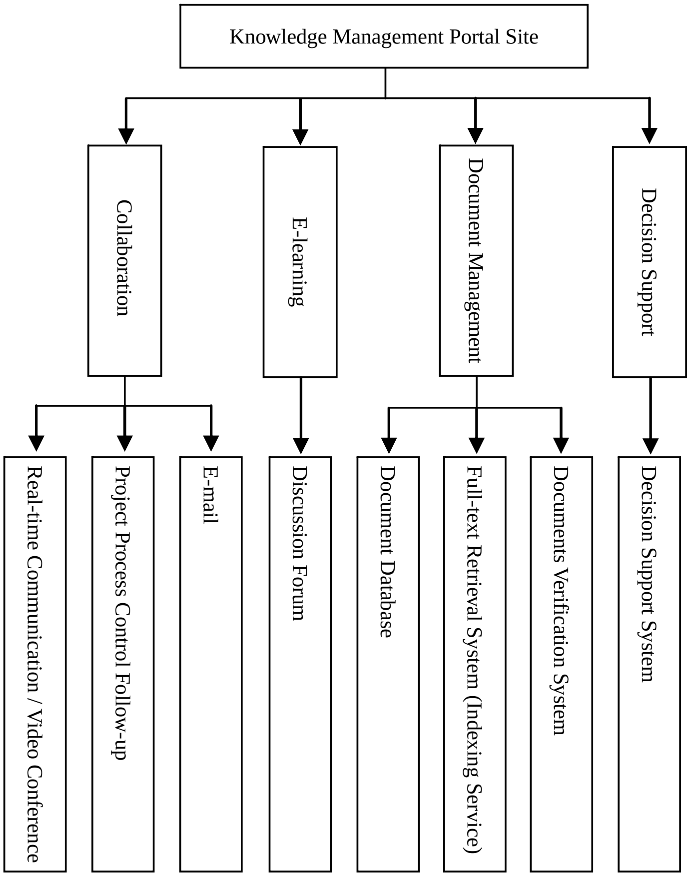

Figure 4.
Configuration of KM portal site system functions

2003 Server and Web Server serves mainly as the operating system, Microsoft IIS6.0 and SQL Server 2000 are used for database applications, and Microsoft Sharepoint Portal Server 2003 software is used for editing programming languages. Moreover, the ASP.NET technology is utilized for web customization. The prototype structure of an information portal site constructed is shown in Figure 6, which not only covers a variety of system functions, but also meets the actual requirements for a knowledge portal site system in the semiconductor industry.

6. Conclusion and suggestion

The semiconductor industry in Taiwan has to cope with keen competitions of fast changes in product development technologies and processes leading to a shorter and shorter product life cycle. Consequently, businesses related to the semiconductor industry need to set up an efficient and useful KM system. To avoid making the same

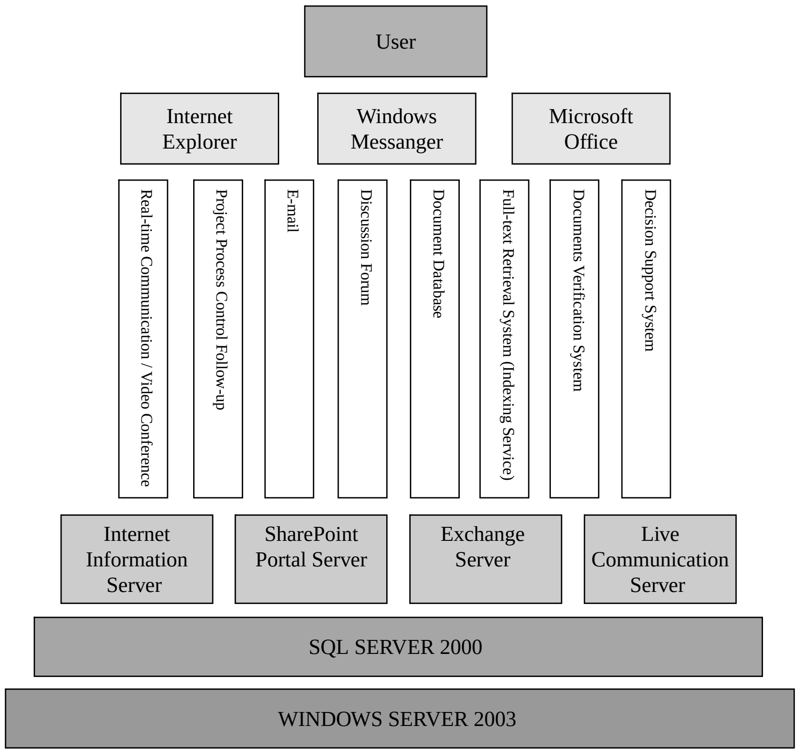

Figure 5. Configuration of KM portal site system functions

mistakes while introducing a KM system to semiconductor manufacturers in Taiwan and to save time required for solving technical problems, actual cases are investigated and a KM system prototype is established in this research to provide reference for the semiconductor industry when introducing a KM system.

We propose a mechanism to determine the key objectives to be improved of KM system. It includes three parts. The performance evaluation matrix was modified to set up a standard performance matrix for system introduction. The importance weights of models related to KM via the AHP and after consulting experts' opinions. The method of QFD was integrated for the system models of a KM system and correlation weights of key objectives to be improved.

The analytic results indicated eight models needed to be improved, document database in M9, full-text retrieval system (indexing service) in M10, e-mail in M2, discussion forum in M7, real-time communication/video conference in M1, decision support system in M14, project process control follow-up in M4, and documents verification system in M11. From the results, it is found that the document accuracy and searching function are important. Correct and comprehensive information and powerful retrieval system is the fundamental part of KM system. Commutation channel and platform are also important. In addition, the decision support system and

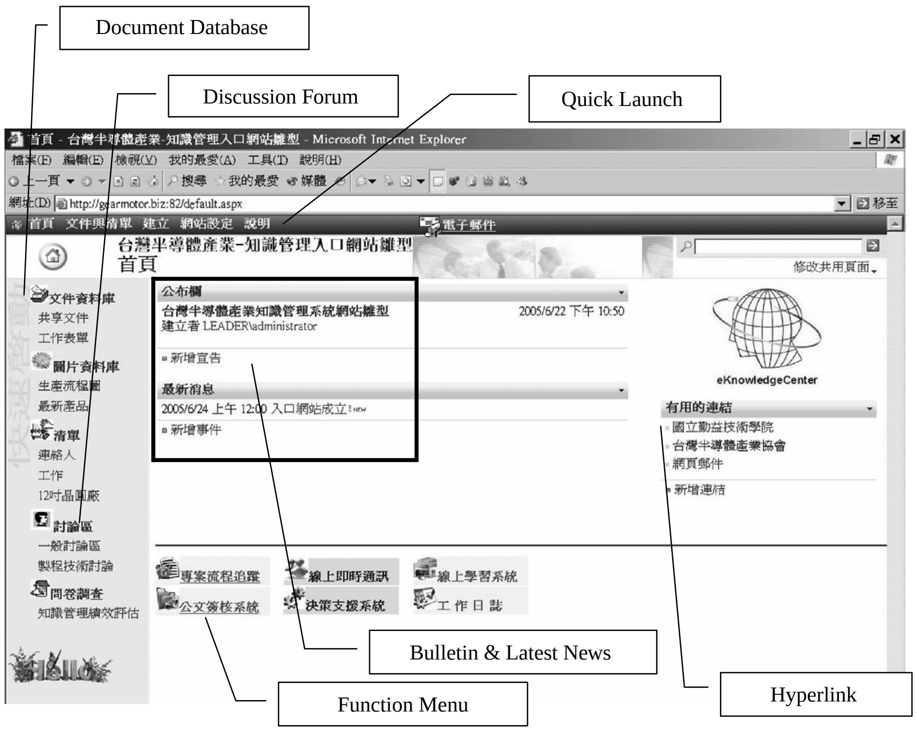

Figure 6.
Main screen of knowledge management portal site

project control providing more managerial intelligence are the key components for semiconductor KM systems.

Through the proposed mechanism, the performance of introducing a KM system can be evaluated quickly via the performance matrix provided and investments in resources can be adjusted to enhance easiness and reduce costs of system introduction efficiently. The performance of introducing KM system models to the semiconductor industry will be assessed and analyzed by the AHP-QFD analysis model so as to locate rapidly the key system models to be established urgently. In this way, the performance of introducing a KM system will be increased efficiently at the lowest cost within the shortest period of time. However, because the investigated samples in this study were the semiconductor industry members in Taiwan, the generalization need maybe need further verification by investigating comparing the objectives to improve under different countries and industries.

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