Performance Evaluation Method and Algorithm of Knowledge Management for Product Innovation Design

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Abstract—**This paper presents a discussion of knowledge management performance evaluation index and evaluation methods for product innovation. The content of knowledge management and the flow of knowledge in product innovation process are analyzed. According to the purpose of performance evaluation and combined with the characteristics of product innovation, the knowledge management performance index for product innovation is established, and the specific evaluation method and algorithm are described. The fuzzy comprehensive evaluation process is discussed.**

Index Terms—**product innovation, knowledge management, performance evaluation**

I. INTRODUCTION

With the life cycles of modern product design are getting shorter and the customer's growing demand for personalized, product innovation has become an important strategic choice for the enterprise to win a long-term development in the fierce market competition [1-3]. Knowledge management for product innovation process enriched the business management content. Internal the same innovation projects and between different product innovation projects, knowledge management emphasizes the sharing of knowledge within the project and cooperation between different projects [4,5]. Knowledge management plays an important role for product innovation process. It affects the efficiency of product innovation and the results. Therefore, it is particularly important to evaluate how important the knowledge management promotes the process of product innovation. Through evaluate the performance of knowledge management for product innovation, it provides a basis for the enterprise to develop a scientific and rational knowledge management strategy. Thus improve the efficiency of product innovation process and accumulate experience for the next phase of product innovation process [6,7]. This paper established the product innovation performance index based on the purpose of the performance evaluation and the characteristics of product innovation. This can provide some reference for relevant research and provide a theoretical reference for enterprises to improve product innovation capability.

II. KNOWLEDGE CONTENT AND FLOW IN PRODUCT INNOVATION

There are many ways for innovation, but they all need a lot of existing knowledge and experience to support. Specifically, it includes scientific principles, technical knowledge, social knowledge, experience, success cases and even failures, and so on [8,9]. It is a source of innovation. Knowledge is the main raw material for product innovation.

Product innovation is a process of knowledge creation, development, transfer and application. It's also a cycle process of continuous improvement. Knowledge generation is a process of new knowledge discovery and created. Knowledge developments reprocess the knowledge which the enterprise already have or get. Its makes the existing knowledge standardized and explicit that makes people easy to identify and understand. Knowledge transfer can make other people use knowledge more effectively by the publications and electronic publications. It also can transfer through education and training activities and personal teach that makes the knowledge to be more widely used. The application of knowledge is a process of make the knowledge meet the customers' needs. This process transforms the knowledge into new products or services by product innovation. Customers enjoy using the product or service and feedback the information include the evaluation of the product and their recommended and customer's experience. And the developer based on feedback combined with new market demands start the next stage of product development. And this process will be repeated circular. The process of knowledge flows as figure 1.

The division of stage of the product innovation process is consistent with the knowledge flow process. Different stage of product innovation process is corresponding with specific knowledge flow process. The concept design stage produces the "original knowledge" based on demand and product application requirements. Production planning stage and detailed design stage application knowledge to production process and providing product. Mass-production/ selling stage transfer the knowledge into product to meet customer's demand. Compared with the product innovation process, the knowledge flow stage set aside a specific form of product innovation and enable enterprises more accurately grasp the law of knowledge flow in the product innovation process.
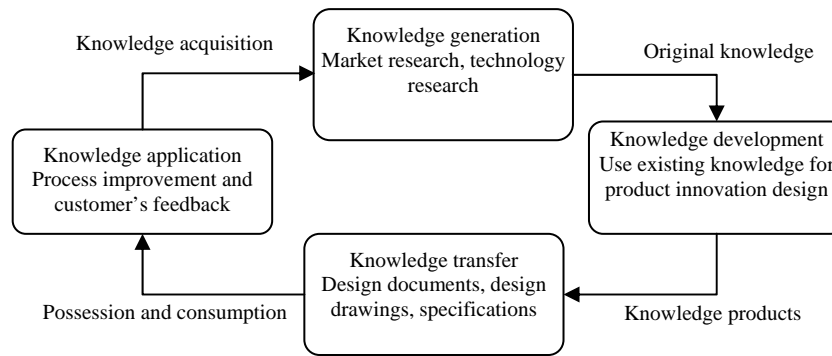
Figure 1. Knowledge flow in product innovation process

III. KNOWLEDGE MANAGEMENT PERFORMANCE EVALUATION INDEX

According to the purpose and principles of performance evaluation and reference relevant research on knowledge management performance evaluation at home and abroad, The paper sorted out knowledge management performance index for product innovation. This index including knowledge capital, knowledge innovation capital, technology capital, market capital, economic efficiency, competitive position 6 indicators and 18 secondary indicators, such as shown in table 1.

Product innovation and development must need a lot of existing knowledge and experience support. It will also create new knowledge when application knowledge in the product development process. The utilization rate of existing knowledge and the knowledge exchange rate in product development has important implications for product innovation success. Therefore, through knowledge management, knowledge innovation capability improves as one aspect in the product development process is needed to evaluate. And knowledge capital must be considered in the enterprise knowledge management performance evaluation process.

Product innovation approach is varied. Product innovation is the process of integrate internal and external resources and cooperate with different departments to use the existing knowledge. It improves the innovative capability by continuous learning and using the knowledge. The evaluation of this indicator include three aspect as increase rate of the number of cooperative projects with research institutions, co-operation project success rate, developers capacity of utilization and learning knowledge increase to reflect the knowledge management performance for product innovation.

TABLE I. KNOWLEDGE MANAGEMENT PERFORMANCE EVALUATION INDEX

Knowledge management performance evaluation index for product innovation	knowledge capital S1	Increase rate of the knowledge resources K1
		Utilization rate of inventory knowledge K2
		The frequency of knowledge exchange improve K3
	knowledge innovation capital S2	Increase rate of the number of cooperative projects with research institutions K4
		Co-operation project success rate K5
		Developers capacity of utilization and learning knowledge increaseK6
	technology capital S3	R&D speed and number increase K7
		R&D success rateK8
		Increase rate of the number of patent applications K9
	market capital S4	Market share K10
		Consumers' confidence on brand K11
		Sales increase rate K12
	economic efficiency, S5	Sales profit increase rate K13
		Total assets of remuneration increase rate K14
		Percentage of innovative product revenue of total revenue K15
	competitive position S6	Enterprise image improve degrees K16
		Enterprise market reputation K17
		Sustainable development level K18

Technology capital include three indicator as R&D speed and number increase ,R&D success rate, increase rate of the number of patent applications. Technology and knowledge are closely related and knowledge largely based on technical as their form of expression. The nature of technology capital is the integration knowledge and information that owned by the enterprise to support product innovation. This knowledge which attached to the developers and the organization itself reflected through product innovation process. And based on this process, the paper chose three secondary indicators reflect the technological capital level.

Market capital is the potential of market-related intangible assets owned by enterprise. Finally, the product of the product innovation development must selling on the market, market capitalization has become an important aspect of knowledge management performance evaluation. It is includes a variety of brands, customers and their trust , Sales increase rate, market share, Supply and sales business relationship, strategic alliances, customer satisfaction, customer relationship and other factors. The secondary indicators include three indicators as market share, consumers' confidence on brand, sales increase rate.

The ultimate purpose of knowledge management for product innovation process is to realize the economic benefit of enterprise growth .So the evaluation of economic indicators is essential in this index. The paper chose sales profit increase rate, total assets of remuneration increase rate, percentage of innovative product revenue of total revenue to evaluate the knowledge management performance for product innovation.

The core competitiveness of the enterprise finally reflected in profitability, market share, enterprise image and public recognition of enterprise products and services and so on. Different enterprise displays different enterprise competitive characteristics which is also the unique performance of the core competitiveness of the enterprise

IV. PERFORMANCE EVALUATIONS METHOD AND ALGORITHM

Some of the indicators of knowledge management performance evaluation index for product innovation are constructed in this paper. And the diversity and ambiguity feature indicate that the fuzzy comprehensive evaluation method is the best option. So we can use AHP (Analytical Hierarchy Process, AHP) to determine the weight of each indicator, and the fuzzy comprehensive evaluation method for comprehensive evaluation.

Here, an enterprise sample is used for the application study of the above method of performance evaluation. Main business of the enterprise is development of electronic components, design and production. It is an enterprise of high level technology, management science, and developed a knowledge management strategy. It is suitable for empirical research.

Five experts are invited to evaluate score for the index system. These experts involved in business managers, research personnel, and independently evaluated score with management experience and understanding.

Total evaluation index is as shown in table 2. Secondary evaluation index is as shown in table 3.

TABLE II. TOTAL EVALUATION INDEX AND ANALYSIS CALCULATION

	S1	S2	S3	S4	S5	S6	w_i^0	
S1	1	1/2	1/3	1/4	1/5	1/3	0.053	
S2	2	1	2	1	1/3	1	0.148	
S3	3	1/2	1	1	1/3	2	0.141	$\lambda_{max} \approx 6.318$
S4	4	1	1	1	1/3	1/2	0.133	$C.I. = 0.064 < 0.1$
S5	5	3	3	3	1	3	0.384	
S6	3	1	1/2	2	1/3	1	0.141	

TABLE III. SECONDARY EVALUATION INDEX AND ANALYSIS CALCULATION

S1	K1	K2	K3	w_i^0		S2	K4	K5	K6	w_i^0	
K1	1	1/3	1/5	0.105		K4	1	1/5	1/3	0.105	
K2	3	1	1/3	0.258	$\lambda_{max} \approx 3.038$ $C.I. = 0.019 < 0.1$	K5	5	1	3	0.637	$\lambda_{max} \approx 3.038$ $C.I. = 0.019 < 0.1$
K3	5	3	1	0.637		K6	3	1/3	1	0.258	
S3	K7	K8	K9	w_i^0		S4	K10	K11	K12	w_i^0	
K7	1	1/2	2	0.297		K10	1	2	1/5	0.187	
K8	2	1	3	0.540	$\lambda_{max} \approx 3.009$ $C.I. = 0.005 < 0.1$	K11	1/2	1	1/4	0.127	$\lambda_{max} \approx 3.094$ $C.I. = 0.046 < 0.1$
K9	1/2	1/3	1	0.163		K12	5	4	1	0.686	
S5	K13	K14	K15	w_i^0		S6	K16	K17	K18	w_i^0	
K13	1	5	3	0.637		K16	1	1/3	1	0.21	
K14	1/5	1	1/3	0.105	$\lambda_{max} \approx 3.039$ $C.I. = 0.019 < 0.1$	K17	3	1	2	0.55	$\lambda_{max} \approx 3.018$ $C.I. = 0.009 < 0.1$
K15	1/3	3	1	0.258		K18	1	1/2	1	0.24	

We use fuzzy comprehensive evaluation method for knowledge management performance evaluation and the steps as follows:

1) Determining the evaluation index and divided these into s subsets and noted as: U_1, U_2, $\cdots$, U_s, and satisfy the conditions:

$$U = \{U_1, \ U_2, \ldots, \ U_s\} \quad , \quad U_i \cap U_j = \Phi(i \bullet j) \quad , \quad \text{and}$$

$U_i = \{U_{i1}, \ U_{i2}, \ldots, \ U_{in}\}$, $i=1, 2, \cdots, s$, n is the number of elements of U_i. Here, $s=6$, $n=3$.

2) Make all the reviews set of the evaluation indicators: $Y = \{Y_1, \ Y_2, \ldots, \ Y_m\}$.

3) Take single-index evaluation for each evaluation indicators and draw the index evaluation matrix: $R_i = (r_{ijk})_{ni+m}$ where $i=1, 2, \cdots, s$; $j=1, 2, \cdots, n_i$; $k=1, 2, \cdots, m$. And r_{ijk} means the degree of subordinate of X_{ij} under reviews of Y_k. We use expert evaluation method for comprehensive evaluation and according to the actual significance determine the indicators evaluate matrix R_i. Detailed process is: Each expert give number grade for each of the indicators X_{ij} based on the reviews and the grade range in [0-1].And last: $\sum_{k=1}^{m} Y_k = 1$. After score for each indicator in each of the reviews, calculate the average score as the final score. And this score is the degree of subordinate of on correspond reviews.

4) Give each indicator weight: $W_I = \{a_{i1}, \ a_{i2}, \ldots, \ a_{im}\}$, where: $\sum_{j=1}^{n_i} a_{ij} = 1$

5) The final reviews are : $B_i = W_i \bullet R_i = \{b_{i1}, \ b_{i2}, \ldots, \ b_{im}\}$, $i=1, 2, \cdots, s$.

6) Regard U_i as a separate element and Bi as the evaluation vector of U_i , that could form the fuzzy evaluation matrix R of U to V:

$$B_i = \begin{pmatrix} B_1 \\ B_2 \\ \cdot \\ \cdot \\ \cdot \\ B_j \end{pmatrix} = \begin{pmatrix} b_{11} & , & b_{12} & , & \ldots & , & b_{lm} \\ b_{21} & , & b_{22} & , & \ldots & , & b_{2m} \\ & & \cdots & & & \\ & & \cdots & & & \\ & & \cdots & & & \\ b_{j}1 & , & b_{j2} & , & \ldots & , & b_{jm} \end{pmatrix} = \begin{cases} 0.064 & 0.126 & 0.279 & 0.411 & 0.121 \\ 0.011 & 0.074 & 0.364 & 0.362 & 0.190 \\ 0 & 0.046 & 0.162 & 0.438 & 0.354 \\ 0.081 & 0.019 & 0.350 & 0.350 & 0.200 \\ 0 & 0.085 & 0.491 & 0.273 & 0.152 \\ 0.055 & 0.100 & 0.355 & 0.369 & 0.121 \end{cases}$$

According to weight of importance of U_i in U, $w = \{a_1, \ a_2, \ldots, \ a_1\}$, calculate the final reviews vector: $B = W \bullet R = (b_1, \ b_2, \ldots, \ b_m)$

7) Calculate the final score：G=BVT.

$$G = \begin{bmatrix} 0.023 & 0.073 & 0.377 & 0.340 & 0.186 \end{bmatrix} \bullet \begin{bmatrix} -5 \\ -3 \\ 1 \\ 3 \\ 5 \end{bmatrix} = 1.992$$

According to the result, knowledge management performance of the enterprise is between general and good. The result is match with actual situation of the enterprise.

V. CONCLUSIONS

Knowledge has become an important factor of production. Implementation knowledge management is an important strategic choice for enterprises gain a competitive advantage in the fierce market competition. Knowledge management performance evaluation for product Innovative have great significance for enterprise to develop innovative policies and product innovation strategic objectives. It also helps the enterprise improve its ability of product innovation and the level of innovation management. This study of knowledge management performance evaluation for product innovation designed to provide a reference for the relevant research and provide a theoretical reference for enterprises to improve product innovation capability.

REFERENCES

[1] Mylnikov. L.A., "A system view of the problem of the modeling and control of production innovations." *Sci. Tech. Info. Proce.*, vol. 39, no. 2, pp. 93-106, 2012. http://dx.doi.org/10.3103/S0147688212020098

[2] T. Kevin C., E. Waleed, "An intelligent system based on concurrent engineering for innovative product design at the conceptual design stage." *Int. J. Adv. Manu. Tech.*, vol. 63, no. 5, pp. 421-447, 2012. http://dx.doi.org/10.1007/s00170-012-3932-7

[3] G. Ian, A. Abu Khari Bin, "The development of an online support tool for the teaching and learning of the IEEE standard 1500 for embedded core-based integrated circuits." Int. J. Online Eng., vol. 8, no. 4, pp. 42-49, 2012.

[4] C. Su, Y. Chen, S. David, "Managing product and customer knowledge in innovative new product development." *Int. J. Tech. Manag.*, vol. 39, no. 1, pp. 105-130, 2007. http://dx.doi.org/10.1504/IJTM.2007.013443

[5] M. Marjan, A. Shamsuddin, D. Siti Zawiah Md et al., "A framework for sharing knowledge in product development by E-collaboration through project management." *Res. J. Appl. Sci. Eng. Technol.*, vol. 4, no. 6, pp. 649-659, 2012.

[6] C. Kathryn, O. David, "A collaborative knowledge management tool for product innovation management." *Int. J. Tech. Manag.*, vol. 26, no. 1, pp. 53-67, 2003. http://dx.doi.org/10.1504/IJTM.2003.003144

[7] N. Somchai, I. Barbara, "Managing knowledge in new product and service development: A new management approach for innovative research organizations." *Int. J. Tech. Manag.*, vol. 28, no. 7, pp. 667-684, 2004. http://dx.doi.org/10.1504/IJTM.2004.005776

[8] G. Kamal, N. Abdollah, "The effect of country of origin on purchase intention: The role of product knowledge." *Res. J. Appl. Sci. Eng. Technol.*, vol. 4, no. 9, pp. 1166-1171, 2012.

[9] S. Ravi, M. Neha, R. Samuel, B. Alok, A. Sourish, "A collaborative framework to minimise knowledge loss in new product development." *Int. J. Prod. Res.*, vol. 51, no. 7, pp. 2049-2059, 2013. http://dx.doi.org/10.1080/00207543.2012.701779

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