PERFORMANCE EVALUATION OF THE CONSTRUCTION KNOWLEDGE MANAGEMENT SYSTEM—A CASE STUDY OF AN A/E CONSULTING FIRM

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ABSTRACT: More and more organizations in construction industry adopt knowledge management system (KMS) to facilitate process of creating, acquiring, capturing, sharing, and using knowledge so as to improve the competitiveness, productivity and efficiency of their organization. In spite of the tremendous efforts devoted to KMS, the return of investment on KMS is usually a black box to the investor due to the lack of a systematic framework for performance evaluation of the KMS. This paper aims at fulfilling such need. A conceptual performance evaluation framework is proposed based on Balanced Scorecard (BSC) method. Then a preliminary case study is conducted to assess the applicability of the proposed framework in an A/E consulting firm to evaluate the performance of KMS.

1. INTRODUCTION

Knowledge management (KM) and learning organization (LO) have been recognized as important new approaches for improving competitiveness and innovation for organizations [1]. In the past decade, more and more organizations and firms in the construction industry of Taiwan have adopted knowledge management system (KMS) in various forms and functionalities to facilitate process of creating, acquiring, capturing, sharing, and using knowledge so as to improve the competitiveness, productivity and efficiency of their organization. In spite of the tremendous efforts and resources devoted to the development and operation of KMS, the return of investment on KMS is still a black box to the investor. The key is lack of a systematic framework to evaluate the performance of the KMS.

There are many reasons for the lack of the abovementioned performance evaluation framework: (1) the value of knowledge is not easy to measure until it is realized in a form that generates physical return to the organization; (2) the form of knowledge is difficult to describe and record, not all types of knowledge is recognizable; (3) the activity of KM is complicated and sometimes intangible, not all knowledge created is recordable and quantifiable; (4) the return of organization's intelligence property (IP) is not immediate after creation, the future value of IP is unquantifiable. Due to the reasons described above, most existing performance evaluation systems for KMS are not product- but process- oriented, which means the performance evaluation of a KMS is based on the indicators observed during the process of knowledge creation rather than the results of knowledge application.

The limitation of the existing process-oriented performance evaluation systems for KMS is obvious, since without the hard evidence of investment return. It has hindered the application of KMS due to the difficulty to persuade the top management for more investment on KMS. Moreover, without a systematic framework of performance evaluation for KMS, best strategies for resources allocation and bottleneck resolution in a KMS is hard to found so that the performance of KMS cannot be further improved. A nature desire is to develop a systematic framework for performance evaluation of KMS, which links the process indicators of a KMS to the investor's business objectives so that the investment of the resources and efforts convert to the outputs.

This research aims at developing a quantitative performance evaluation framework for a KMS based on Balanced Scorecard (BSC). With the strategic map of BSC, systematic strategy for improving the performance of a KMS can be identified. A real world case study is conducted to preliminarily test the proposed framework in an A/E consulting firm. The KMS of the case firm was throughout studied. Activities related to knowledge creation, acquisition, capturing, sharing, and usage were monitored to record the required key performance indices (KPI) of the proposed framework. Quantitative ad qualitative benefits of the KMS were recognized and recorded to evaluate the performance of the KMS.

The rest of the paper is presented in the following: review of related literature is described next; then background information of the case A/E firm is introduced; following that, the proposed BSC based framework for performance

evaluation of a KMS is described in details; preliminary results for application of the proposed framework in the case A/E consulting firm is analyzed; finally the findings of the case study are discussed.

2. LITERATURE REVIEW

After thoroughly reviewing the literature, it was found that very few research reports were found on performance evaluation of a KMS. The most related work discovered in literature was a work done by del-Rey-Chamorro et al. in Cambridge University [2]. They developed an eight-step framework to create performance indicators for knowledge management solutions. 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 can be very useful for creating performance indicators of a KMS, however, their work was primarily developed based on the observations of KMS in manufacturing industry.

A recent work reported by Mezher et al. on a KMS in a mechanical and industrial engineering consulting firm [3] in middle-east is closely related to this paper. Their paper details the step-by-step implementation of KMS in the case company and lessons learned on the benefits of KMS implementation. Unfortunately, their work didn't describe the evaluation of the performance of KMS. However, at the end of the paper, the authors addressed: "(Future researchers) should set up some quantitative measures to show the financial benefits of the KMS". It pointed out the importance of quantitative performance evaluation for a KMS.

Even though previous work on quantitative performance evaluation of KMS is rare, the similar study in performance management (PM) area is quite plenty even in construction industry. 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 [4]. 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) [5], European Foundation for Quality Management (EFQM) excellence model [6], and Key Performance Indicators (KPI) [7]. The above systems provide useful indicators that can be adopted for performance evaluation in the present research.

3. DESCRIPTION OF CASE A/E FIRM

This section describes some information of the case A/E firm that has been selected for study in this research.

3.1 Basic Information

The case A/E firm is one of top three 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 headquarter located in Taipei, the other 900 are allocated in branches and site offices around the island. Headquarter, 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 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.

3.2 Products and Services

The case A/E firm is a multi-group international consulting firm, which is structured around a number of departments. These departments are either engineering or service departments. Service departments are those help engineering departments achieve their goals. The above departments complement each other and ultimately produce complete fully integrated design documents. These documents are preliminary technical studies, plans of design drawings, technical economic feasibility studies, specifications, methods of operation of projects, and Tender documents. Services provided by the case A/E consists of the following area:

- Studies, investigations and surveying
- Highways and freeways
- Railways and high speed rail
- Rapid transit systems
- Airport works
- Harbor works
- Bridges and structures
- Architecture
- Urban planning /land development
- Environmental engineering
- Tunnels & geotechnical engineering
- Electrical & mechanical engineering
- Information network applications
- Hydraulic/water resources engineering
- Information technology and systems
- Traffic control and management
- BOT general consultant services
- Construction supervision and management
- Testing and monitoring

3.3 KMS Implementation

The implementation of KMS in the case A/E firm started four years ago. Unlike most of other examples of KMS implementation, the case A/E firm chose to develop the KMS completely by their own staffs without help of 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 IT should be included in order to resolve the technique problems encountered in implementation of prototype system. A commercial software, MS™ SharePoint® was adopted to develop 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. More that 40 communities of practice (COP) were established. The number of COP is varying based on an enter-and-exit regulation. That is, continuous evaluation of COP is performed to determine whether it should be maintained or closed 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. To date, the KMS has been operating for three years. The KMS has been modified quite a bit from its prototype three years ago. One of the most significant modifications was the introduction of SOS system for emergent problem solving.

3.4 SOS System

The SOS system is a special design of the KMS of the case A/E firm, which provides a tentative forum for emergent problem encountered by engineers/managers. Once the problem is posed as SOS-problem, it is posted in the SOS board on the first page of the KMS for emergent discussions. Such arrangement forces every participant of KMS to take a look at the posed problem. So that it generally receives attentions and usually has a better chance to be solved by responders. Problems posed on the SOS board receive no response within one working day will be automatically removed and transferred to relevant COP. After then, it becomes regular topic for discuss in COP.

3.5 System Outlook

The outlook of the case KMS of the case A/E firm is shown in Figures 1~5. Figure 1 shows the enterprise information portal (EIP) of the case A/E firm, which is also the main page of the case KMS.

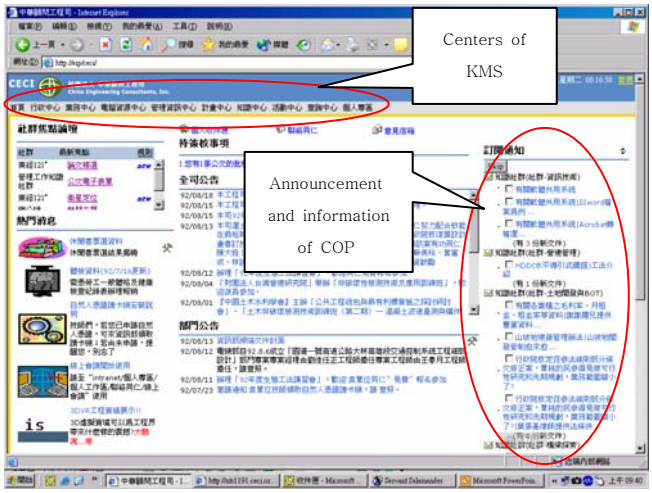

Figure 1. EIP of the case KMS

Figure 2. shows the list of COP's in the case KMS. There are more than 40 COP's in the KMS. The number of COP's is varying according to an enter-and-exit regulation.

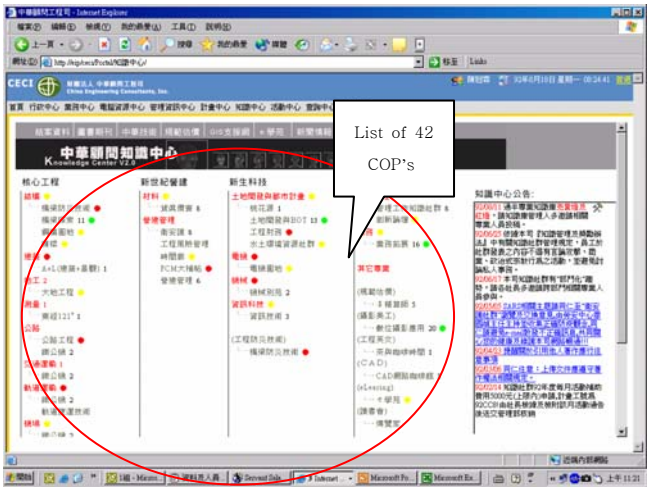

Figure 2. List of COP's in the case KMS

Figure 3. shows the records of KM activities in an example COP (COP of Construction Management).

Figure 3. Example COP of the case KMS

Figure 4. shows the document retrieval function provided by the case KMS.

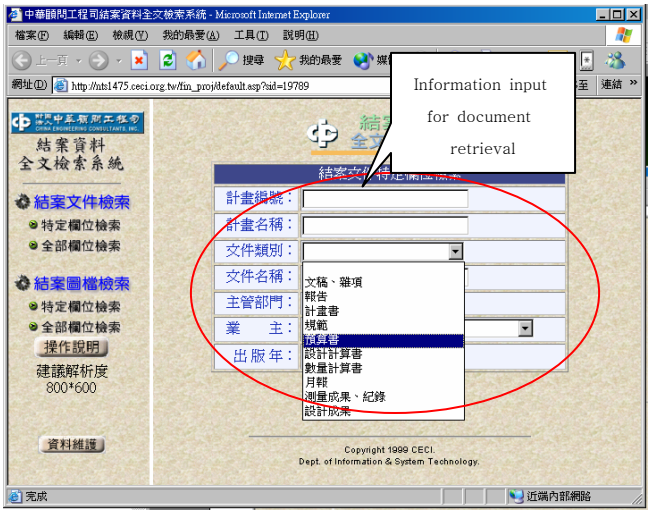

Figure 4. Document retrieval of the case KMS

4. ESTABLISHING PERFORMANCE EVALUATION SYSTEM FOR KMS

This section describes the performance evaluation system established for the KMS of the case A/E firm.

4.1 Methodology

As discussed in the previous sections, there has been very little literature on performance evaluation of KMS due to the difficulties of recording and recognition of KM activities and the quantification of the value of IP. This paper adopts the concept of del-Rey-Chamorro et al. [2] in developing the framework of performance evaluation and the idea of Bassion et al. [4] in linking the performance indicators of KMS to business objectives of the organization. The methodology of Balanced Scorecard (BSC) for structuring evaluation framework into four perspectives (i.e., learning and growth, internal process, customer, and financial) is adopted to link the KMS performance indicators (leading indicators) with business objectives (lagging indicators). Both of the leading and lagging indicators were identified via literature reviews and brain storming by the research team. They were then confirmed by interviews with the experienced engineers and staffs of the case A/E firm.

The BSC provides a framework for quantitative evaluation of the KMS performance in strategic level. It however does not help in analyzing the knowledge creation pattern of the participants who are involved in the operation of the KMS. The Nonaka's "Theory of Organizational Knowledge Creation (TOKC)" [8] provides a micro view for analyzing behavior of the participants involved in KMS. In application of TOKC, example scenarios of knowledge management (KM) solutions are analyzed with the knowledge creation spiral proposed by Nonaka to identify patterns of knowledge creation in COP. Strategies for improving knowledge sharing and knowledge creation are then proposed.

In the final stage of performance evaluation, the tangible benefits gained from KM solution should be quantified in order to link the KMS performance indicators to business objectives. Such analysis is not included in this preliminary study.

4.2 Leading Performance Indicators

As discussed in del-Rey-Chamorro et al. [2], the leading performance indicators should represent the process performance of KMS to show the measurable operational actions of the daily routines. In the proposed framework, there are three perspectives of the leading indicators: (1) learning and growth—including library usage (L_1), training participation (L_2), e-Learning participation (L_3), KMS participations after work (L_4), and the number of professional licenses held by staffs (L_5); (2) internal process—including usage of project final reports (I_1), number of SOS requests (I_2), number of outstanding COP's (I_3), number of posted articles in KMS (I_4), number of responding articles in KMS (I_5); and (3) customer—including staff's satisfaction on KMS (C_1), staff's satisfaction on KMS activities (C_2), client's satisfaction ratio (C_3), and client's complaint ratio (C_4).

4.3 Lagging Performance Indicators

The lagging performance indicators represent the business objectives of the organization. In BSC, such indicators are usually related to financial indices of the company. In evaluating the performance of the KMS in an A/E consulting firm, the lagging performance should focus on the key resource of the firm, i.e., human resource. As a result, the productivity index is considered the most important lagging performance indicator (F_1) of the framework. The other two lagging performance indicators were considered but denied by the top management of the firm are profitability index (F_2) and ratio of successful bids (F_3). The reason for rejecting these two indicators was that these indicators are not influenced only by the performance of KMS. In some cases, other factors (such as the policy of the client and environmental climate) may play more important roles.

4.4 Integrated Framework and Strategic Map

The leading and lagging performance indicators discussed above are integrated to form a BSC for performance evaluation of the KMS in the case A/E firm. The integrated preliminary BSC depicted a strategic map shown in Figure 5.

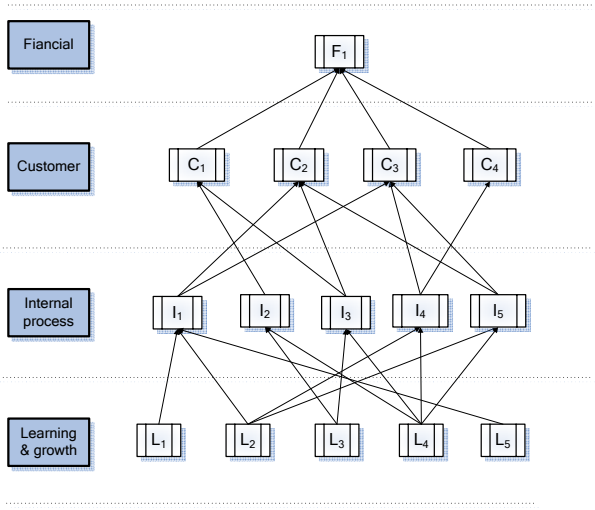

Figure 5. Strategic map of the integrated BSC

4.5 Micro Analysis Model

The Nonaka's four dimensional knowledge conversion model is utilized for analyzing the participant's behavior in KMS. The concept of Nonaka's spiral of organizational knowledge creation is depicted in Figure. 6, where the vertical axis discriminating knowledge into "explicit" and "implicit" categories. On the other hand, the horizontal axis shows the ontology of knowledge creating entities, e.g., individual, group, organization and inter-organization. There are four dimensions for knowledge conversion: (1) Socialization—transferring tacit knowledge to tacit knowledge; (2) Externalization—transferring tacit knowledge to explicit knowledge; (3) Combination—transferring explicit knowledge to explicit knowledge; (4)

Internalization—transferring explicit knowledge to tacit knowledge. Among those, the socialization is related to group process/ organization culture. Actions that building a better knowledge sharing culture or atmosphere can improve socialization; the externalization process is currently supported with no organizational theory; the combination is related to information processing, therefore software and hardware systems can stimulate combination activities; and internalization is related to organizational learning (OL), approaches of OL can be adopted to improve internalization process.

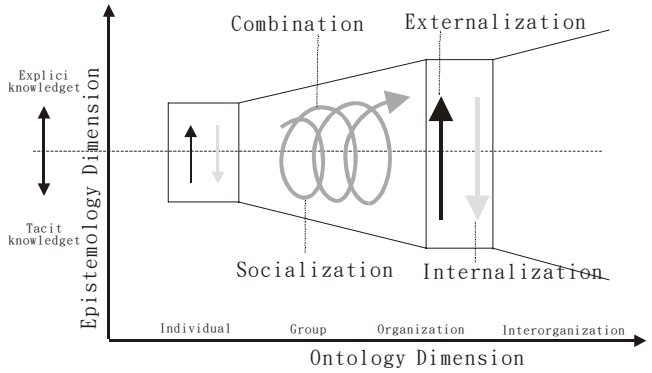

Figure 6. Spiral of organizational knowledge creation [8]

With the 4-dimensional knowledge creation model, the behavior of the members involved in KMS can be analyzed, and the relevant organizational theories can be proposed to improve the knowledge creation processes.

5. PRELIMINARY RESULTS

This section describes the preliminary results of the performance evaluation on the KMS of the case A/E firm.

5.1 Performance Evaluation Framework

The proposed BSC performance evaluation framework has been presented to the top management of the KMS. The responses were quite positive except that some leading indicators need to be revised due to the availability of required information. Moreover, the logic relationships between adjacent levels need to be clarified. For example, the number of professional licenses (L_5) seems not relate to the indicators in internal process. Some indicators (e.g., the profitability index) are important for performance evaluation; however they may be influenced by other factors. There should be some preprocessing for such kind of indicators before they are applied.

5.2 Statistics

According to interviews with the managers of case KMS, there are some quantitative values that can reflect the performance of the case KMS: (1) percentage of staffs participation in KMS—more than 52% of all full-time staffs have participated in KMS in some form; (2) number of COP's—42; (3) number of e-Learning courses—88 professional courses were offered and 254 classes have been opened; (4) total number of drawings stored in KMS—more than 157,000; (5) total number of reports stored in KMS—more than 12,000; (6) number of professional books in KMS—28,000; (7) number of professional journal in KMS—500; (8) satisfaction of participants on KMS—32% highly satisfied and 56% satisfied (totally 88% satisfied).

The above quantitative information reveals the active participations of staffs and the diversified contents of the knowledge repository for the case KMS. Other qualitative information is also interesting. Engineers have altered their momentum of work. Many engineers participate in KMS activities at home after work. Most impressive change has been in the relaxation of geographic and temporal restrictions on problem solving. Traditionally, the problem solving should be performed by job team members who met each other in a meeting at the same time in the same place. With KMS, the posed problem can be discussed on COP 24 hours without any restriction of distance. From the records of SOS cases, it is found that the participants of KMS activities were from offices all around the island and also from some remote islands.

5.3 Analysis of Two SOS Cases

Two sample SOS cases were provided by the case A/E firm for preliminary study. By analyzing the knowledge activities of the two cases, the pattern of knowledge conversions are shown in Figure 7 and 8. It is found that the patterns of knowledge conversion in the fist case was generally following the sequence: socialization (S) → externalization (E) → combination (C) → internalization (I). However, in the second case, sequence of knowledge creation follows: socialization (S) → internalization (I) → combination (C). The creation process is not complete.

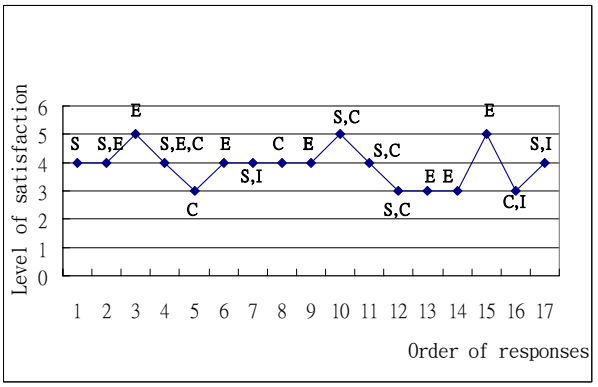

Figure 7. 4-D knowledge creation analysis—Case I

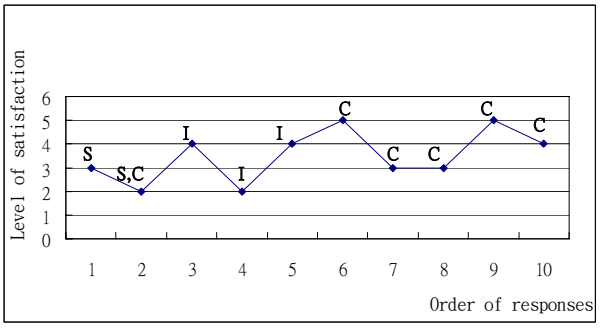

Figure 8. 4-D knowledge creation analysis—Case II

Another interesting finding of the participants' behavior is the occasion of participation in KMS. It was found that more than 1/5 of the articles were posted after work in the two cases (see Table 1). It shows that the KM activities are not restricted to the working hours in the office. It means the case firm benefits from KMS implementation in encouraging her staffs to extend their working hours.

It was found from the responded articles in the two SOS cases that the responders were from all branches and site offices of the firm. It shows a dramatic change in traditional problem solving process from a local, internal-department, and time-consuming process to a global, cross-department, and real-time process. All engineers and managers in the firm were involved in solving the posed problem anytime in the place of his/her office.

Table 1. Timing of responding

Case	Total No. of responses	Responding at work	Responding after work
I	18	15	3
II	11	8	3

5.4 Incentives

In order to promote the KM activities, the manager of KMS has proposed several incentives including: (1) establishing a scoring system to evaluate the KM participation of the individuals of the firm, such scoring system is linked to the individual's performance evaluation system; (2) the KM participations after work are encouraged with higher scores; (3) financial incentives are provided to the manager of each COP for holding learning and growth activities; (4) outstanding COP's are selected and awarded with incentives. It was found from interviews with the managers that the most important incentive was linking the objective of KMS to the goal of individual's growth.

6. CONCLUSION AND FUTURE WORK

Performance evaluation of KMS in construction firms has been a tough and challenging task. Little literature was found to address on this issue. This paper presents a preliminary study on the performance evaluation of the KMS in an A/E consulting firm in Taiwan. A conceptual BSC framework has been proposed for quantitative performance evaluation. The proposed BSC framework links process indicators of the KMS to the lagging indicators of the business objective for the organization, providing casual relationships for and strategic improvement of the KM processes. A micro analysis model wasn proposed based on Nonaka's 4-dimensional knowledge creation spiral. It was found from two SOS cases that the pattern of knowledge creation indicates specific characteristics of the problem. Some statistics from the case study also showed successful implementation in the case A/E consulting firm. The firm has benefited from KMS in improving its problem solving processes.

Assessment of the BSC indicators is undertaking to verify the proposed BSC framework. Moreover, the quantitative evaluation of lagging financial indicators of the KM solution in each SOS case is also undergoing. The results will be reported in the future.

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