BETTER INPUTS FOR KNOWLEDGE MANAGEMENT INFORMATION SYSTEMS: KNOWLEDGE SHARING MODELING AND THE INCENTIVES SYSTEM DESIGN

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ABSTRACT： Recently, Knowledge Management (KM) has been applied to construction industry. Surprising, there is few studies that address the most fundamental problem in KM: people may prefer not to share their knowledge so as to preserve their intellectual or unique values in the organization. Without the premise of each individual's willingness to share knowledge, there will be no valuable input for the IT system and, thus, no knowledge management at all. This paper aims to model the behavioral dynamics of knowledge sharing and to design an incentive system that may facilitate knowledge sharing for construction companies. In this paper, a game-theory based model will be developed, and the framework for designing an incentive system will be proposed according to the model.

Keywords：Knowledge management, knowledge sharing, Game theory, Knowledge classification

1. INTRODUCTION

Knowledge Management (KM), originated from the resource-based theory that treats valuable resources as the cornerstones of competitive advantage, has drawn immense attentions from practitioners and researchers in many industries. Grant [1] argues that knowledge has emerged as the most strategically significant resource of the firm, and the integration of individuals' specialized organizational capability is crucial to the creation and sustainability competitive advantage.

Recently, KM has also been applied to construction industry, and there have been many discussions regarding how to implement certain information techno-ogies that may facilitate knowledge accessibility. Surprising, there is few studies that address the most fundamental problem in KM: people may prefer not to share their own knowledge so as to preserve their intellectual values in the organization. Without the premise of each individual's willingness to share knowledge, there will be no valuable inputs for the KM. Moreover, the implementation of KM is usually very costly, partly because of the information system serving as the platform for knowledge management.

Since the sharing of knowledge relates to the competitive and cooperative relationships between each member in an organization, we consider game theory a natural methodology to analyze such knowledge sharing problems. In this paper, a game-theory based model will be developed. The model will consider the knowledge characteristics in construction industry and how each rational individual reacts, in terms of sharing knowledge, to these characteristics in an equilibrium. This study is expected to provide both researchers and practitioners a new concept to understand when and how the knowledge will be shared so that one can design an effective incentives system for KM in construction.

2. LITERATURE REVIEW

2.1 What is Knowledge?

Pascarella [2] argues that knowledge could steadily increase corporate assets, such as management system, brand identity, customer information and corporate reputation. According to Wah [3], "knowledge is a highly personal asset, which may include pooled expertise and the efforts of networks and alliances." Stewart [4] regards knowledge a treasure, which is central to an organization's success.

2.2 Knowledge Management and Knowledge Sharing

KM is a process of managing knowledge, not a computer/information technology. Sharda et al. [5] argues that although recent computing and telecomm-nication technologies have provided managers powerful access to more data, the problems of "getting the right information to the right person at the right time, and retaining that information in the organization for future use" have not been solved yet. We argue that knowledge management concerns how to solve the above problems.

However, according to Bates [6], "information sharing is often not encouraged within organizations; in fact, there's often the unspoken belief that one loses power by sharing knowledge." Therefore, knowledge sharing has been identified as a major focus area for knowledge management [7].

Regarding knowledge sharing, Hendriks [7] argues that the sharing needs motivations, and information and communication technology can facilitate the sharing. Ipe [8] argues that knowledge in organization is "dependent on social relationships between individuals for its creation, sharing, and use." According to Ipe, knowledge is usually shared informally, and is very often dependent on the corporate culture.

3. METHODOLOGY

In this study, game theory will be applied to analyze individuals' behaviors of knowledge sharing. We shall briefly introduce some important concepts in game theory.

3.1 Types of Games

There are two basic types of games: static games and dynamic games, in terms of the timing of decision making. In a static game, the players act simultaneously. In a dynamic game, the players act sequentially. Due to the nature of knowledge sharing, the dynamic game will be used for used for analyzing the motivations and conditions for knowledge sharing.

3.2 Game Solution: Nash Equilibrium

As to answer what each player will play/behave in this game, we shall introduce one of the most important concepts: "*Nash equilibrium*." In a Nash equilibrium, each player's strategy should be the best response to the other player's strategy, and no player wants to deviate from the equilibrium solution. Thus, the equilibrium or solution is "strategically stable" or "self-enforcing" [9]. A dynamic game can be solved by maximizing each player's payoff *backward recursively* along the game tree. We shall apply this technique in solving the government rescue game.

4. MODEL OF KNOWLEDGE SHARING

Based on game theoretic analysis, the model is expected to solve for the conditions that determine the knowledge sharing behaviors of employees. Particularly, we want to know when sharing is a possibility and when is impossible, whether the sharing needs any incentives provided by the firm. In section 5, we will then discuss the implications from the model in knowledge management in construction.

4.1 Definition of Model Parameters

The model parameters could be divided into two sets, where one set concerns the employees and the other set concerns the firm.

First, the employees only make their decisions of sharing or not based on their received net payoffs. If the employees have higher net payoffs for sharing their knowledge, they will choose to share, and vice versa. Second, the firm concerns the net monetary benefit obtained only, and will make the decisions that maximizes monetary payoffs.

Note that in some occasion, we will use "sharer" to refer the employee who shares knowledge.

4.1.1 Parameters Regarding Employees

The parameters should have been in the form of utility. However, since the parameters regarding the firm is in monetary term, here, for consistency, we also use monetary term for the parameters regarding employees. Note that the transformation from the utility form and monetary form is out of this paper's scope.

- γ_1: explicit of sharing knowledge. The cost that can be measured in terms of money, time, and effort are defined as explicit cost in this study. The explicit cost is inevitable when people share knowledge. However, it is assumed that the KM's IT platform can significantly reduce γ_1 to an ignorable amount. The platform will be called KM platform thereafter in the paper.
- γ_2: implicit cost of sharing knowledge.

  The cost that is related to the reducing of someone's competitiveness or uniqueness in an organization after sharing his knowledge or know-how.
- γ: overall cost of sharing knowledge. Note that γ is the sum of γ_1 and γ_2.
- ω: reward from the firm for sharing knowledge. The reward may be the explicit reward such as monetary reward and promotion, or the implicit reward such as the praise or encouragement from managers.
- s: side benefit. Here the side benefit is defined as the benefit that is not purposely for rewarding knowledge sharing. For example, some knowledge sharing may help colleagues improve their certain skills and such improvement may turn out to help the "sharer" performs better.

4.1.2 Parameters Regarding the Firm

Based on profit maximization principle, the firm will form the strategies for knowledge management system, including the organizational structure, scope, and incentives system etc. Relevant parameters are as follows.

- c_1: monetary costs for rewarding the knowledge sharers. Note that c_1 is different from ω, since c_1 is the sum of the explicit rewards for each individual.
- c_2: costs of implementing KM platform.
- c: overall monetary costs for knowledge management. Here c is the sum of c_1 and c_2.
- π: Benefits due to shared knowledge.

4.2 Knowledge Sharing Model

Figure 1 shows the game model of knowledge sharing. As shown, there are two players, employees and the firm. At every node for employee's turn, an employee has two choices: "share" or "not share." For a firm, there are two types of nodes. At the first node, the firm decides whether or not to implement KM platform by incurring platform cost, c_2; so the choices are "KM platform" or "no platform." At the firm's second node, representing that the KM platform is in place, the firm decides whether or not to reward the employee's knowledge sharing; so the choices are "Rewards" or "No rewards."

The payoffs of the players are modeled as shown in Fig. 1. For the path [KM platform, Rewards, Share], the payoffs for the firm are π-c, where c includes the costs of platform and rewards, and the payoffs for the employee are $s-\gamma_2+\omega$, where γ_1 is not in the formula as γ_1 is assumed ignorable due to the KM platform. Also note that the costs of the firm are zero when there are no KM platform and thus no needs to reward the use of platform for sharing knowledge. The modeling of other payoffs should be very straightforward to readers.

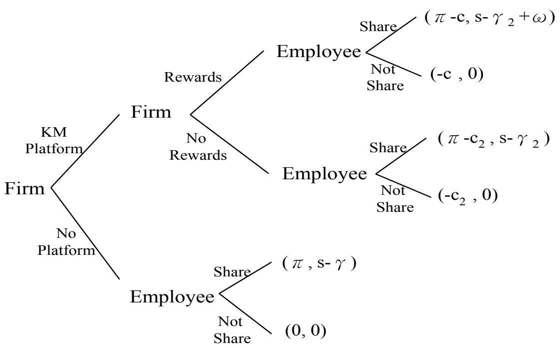

Figure 1. Knowledge-Sharing Game Tree

Note that depending on the characteristics of knowledge, employees, and organizations, the sharer's costs due to knowledge sharing may be quite different. As a result, the firm and employees may have different actions because of different knowledge. For example, if, to the sharer, the knowledge is an important know-how that maintains the sharer's uniqueness in the firm, then the sharer will ask for high reward for sharing knowledge.

By solving the game tree in Fig. 1 backward recursively, we obtain four major scenarios and possible equilibria. We shall derive these equilibria and discuss their implications for KM as follows. Table 1 summarizes the four possible equilibria, where N denotes "No" and Y denotes "Yes."

4.2.1 Case I: Firm[no platform/no rewards] & Employees[share]

If $s-\gamma<0$, and $\pi-c_2<0$, the equilibrium path follows: "no platform" & "no rewards" for firms and "share" for Employees. We shall denote th path using: Firm[no platform/no rewards] & Employees[share]. Note that this type of knowledge can be easily shared without the aids of platform and sharing knowledge will bring the sharer side benefits such as appreciation or better inputs from the teammates who learn the knowledge. For example, teaching colleagues how to operate simple equipments belongs to this case.

4.2.2 Case II: Firm[platform/no rewards] & Employees[share]

If $s-\gamma_2<0$, $s-\gamma<0$, and $\pi-c_2<0$, the firm would build the platform, and the employees would share without rewards. Sharing knowledge of this type will not conflict with the sharer's competitive ability, but the knowledge is more complicated than that of case I and requires higher cost, such time, to share. Thus, the employees are willing to share when the explicit sharing cost is reduced through KM platform. On the other hand, the benefits to the firm due to knowledge sharing can justify the costs of KM platform. For example, knowledge of ?

4.2.3 Case III: Firm[platform/rewards] & Employees[share]

If $s-\gamma_2+\omega<0$, $s-\gamma<0$, and $\pi-c<0$, the firm would build the KM platform, and the employees would share only with rewards. Sharing knowledge of this type will either conflict with the sharer's competitive ability or requires much higher explicit sharing cost than that in case I. Knowledge of this type is even more valuable to the firm than the knowledge in case I since the benefits can justify the costs of both platform and rewards.

4.2.4 Case IV: Firm[no platform] & Employees[not share]

If $s-\gamma<0$ and $\pi-c<0$, there will be no needs to build a KM platform and the employees will not share either. There are two distinct types of knowledge that can fall in this case. The first type is characterized by a very high γ_2 and a medium π. Note that a high γ_2 will then cause a high c, and the high c will need a very high π to justify the cost. Thus, if the knowledge can only bring a medium π, the firm will not implement a KM platform and encourage the sharing through the platform. Knowledge that is the center to personal competitive advantages, but not the firm's competitive advantage, is of this type. Such knowledge may only be needed by very few people, such as top managers or accountants, who already had the knowledge. A better way to deal with such knowledge could be to hire the knowledge owners according to specific needs, instead of urging experts, experienced workers, or specialists to share their knowledge. The second type is characterized by very low or negative values of s and π. This type of knowledge can be regarded as the so called "garbage."

Table 1. Four Possible Game Equilibria

Type	Equilibrium Conditions		KM Platform	Rewards for Sharing	Share or Not
	Employees	Firm			
I	$s-\gamma \square 0$	$\pi-c_2 < 0$	N	N	Y
II	$s-\gamma_2 \square 0$ $s-\gamma < 0$	$\pi-c_2 \square 0$	Y	N	Y
III	$s-\gamma_2+\omega \square 0$ $s-\gamma < 0$	$\Pi-c \square 0$	Y	Y	Y
IV	$s-\gamma < 0$	$\Pi-c < 0$	N	N	N

5. IMPLICATIONS FOR KNOWLEDGE MANAGEMENT IN CONSTRUCTION

Implications for knowledge management can be drawn from the equilibria of the game. The results of the game analysis show that the decisions concerning KM platform and incentives design are complex. For example, we learn that not every type of knowledge should be encouraged to share through a KM platform. Therefore, different strategies should be adopted for different characteristics of knowledge. Here we shall further transform the game equilibria to the implications for knowledge management, namely, 1. how to classify knowledge for platform worthiness, and 2. incentives design.

5.1 Knowledge Classification for Platform Worthiness

Based on the game equilibria, we may categorize knowledge for determining the worthiness of KM plat-orm and incentives design. Here we will define five types of knowledge and their characteristics.

5.1.1 Simple Knowledge

This type of knowledge will generally yield the equilibrium in case I. The simple knowledge is charac-erized by:

- Knowledge complexity: simple. The knowledge can be easily shared and learned in daily normal interactions between employees. Therefore, the explicit cost to the sharer is low.
- Knowledge uniqueness: low. The sharing of knowledge will not affect the sharer's competitive ability inside the organization.
- Knowledge contribution by sharing to competitive advantages (CAs): ranging from low to high. Whereas most simple knowledge, when possessed by individuals, may not be very valuable to a firm, there may be a synergy when simple knowledge is shared and well managed.

This type of knowledge could be general skills, such as the use of MS Words, or task related skills, such as how to efficiently monitor a job site. In many cases, this type of knowledge may be just the so called "tricks" that are easy but useful. A simple database system would be sufficient for managing knowledge.

5.1.2 Complex Knowledge

This type of knowledge will generally yield the equilibrium in case II. Complex knowledge is characterized by:

- Knowledge complexity: medium to high. Due to its complexity, the knowledge cannot be easily shared or learned. The sharing requires significant efforts to organize, store, and communicate the knowledge. Nevertheless, it is assumed that such complexity can also be significantly reduced by a KM platform under a good KM process.
- Knowledge uniqueness: low. Although this type of knowledge may uniquely possessed by certain employees in an organization, such knowledge is not too difficult to obtained or learned from outside the organization, and thus the sharing will not have significant impacts on the sharer's value.
- Knowledge contribution by sharing to CAs: from medium to high. This knowledge in general is more valuable than simple knowledge, and may create more synergies when the knowledge is shared, particularly, in a larger firm.

For example, the experiences or lessons obtained in each assigned construction or consulting project can be considered as complex knowledge. A well designed KM platform can help employees easily summarize their lessons learned, and then organize lessons from individuals so as to create CAs for the firm.

5.1.3 Core Knowledge

Knowledge of this type will usually yield the equilibrium in case III. The sharing of such knowledge creates very important synergies which are strongly related to a firm's core competitive ability. The core knowledge is characterized by:

- Knowledge complexity: from medium to high. This characteristic is the same as that of complex knowledge. KM platforms play an important role in reducing the cost of knowledge sharing.
- Knowledge uniqueness: from medium to high. The core knowledge possessed by employees usually may not be easily learned or obtained from outside the organization. As a result, the sharing of core knowledge may affect the uniqueness of the sharer, and thus, the sharer may demand commensurate payoffs.
- Knowledge contribution by sharing to CAs: from medium to high. Such knowledge will contribute significant to a firms CAs after the sharing and being learned by other employees.

5.1.4 Expert Knowledge

Knowledge of this type will usually yield the equilibrium in case IV. The expert knowledge is characterized by:

- Knowledge complexity: high. The knowledge usually is professionally related and very difficult to transfer to people who are not in the same profession.
- Knowledge uniqueness: from medium to high. One example is when the knowledge is related to some firm specific technology or system, which may not be found elsewhere.
- Knowledge contribution by sharing to CAs: medium. Note that the term "expert" refers to some particular people who are professionally trained. In many cases, the sharing of expert knowledge may not create desired synergy, as the expert knowledge is not desired by other employees. For example, the sharing of the knowledge owned by CEO or CFO will not contribute too much to a firm's CAs.

5.1.5 Garbage Knowledge

This type of knowledge will also yield the equilibrium in case IV. Such knowledge is mainly characterized by:

- Knowledge complexity: low.
- Knowledge uniqueness: low.
- Knowledge contribution by sharing to CAs: negative to low. The sharing to this kind may waste the firm's resources in the processing of such knowledge

In fact, firms should discourage, by negative incentives, the distribution of garbage knowledge.

5.2 Incentives System Design

Husted and Michailova [10] argues that some business environments and organizational cultures are more hostile to knowledge sharing than others. According to our model, the major type of knowledge in an organization and the incentives system may cause such hostility. Implications for KM incentives design can be obtained from the game analysis and knowledge classification discussed above.

- Without incentives, people may prefer not to share their own knowledge so as to preserve their intellectual values in the organization.
- Incentives design should consider three characteristics of knowledge: 1. knowledge complexity, 2. knowledge uniqueness, and 3. knowledge contribution by sharing to CAs.
- Incentives are only needed to encourage the sharing of core knowledge as defined above.
- Negative incentives should be used to discourage the sharing of garbage knowledge.
- The KM platform is not suitable for all companies. KM platform may not bring the desired performance for those companies that are not knowledge intensive and small in company scale.
- Non-monetary rewards should be included in the incentives design system. In fact, many studies show that monetary rewards are not the best effective approach to encouraging employees.
- It is not an economical strategy to promote the sharing of all kinds of knowledge. Some knowledge is not meant to be shared, too expensive or valueless.

6. CONCLUSIONS

In this study we have developed a game theoretic model for analyzing the knowledge sharing behaviors, and defined five types of knowledge. The five types knowledge can be characterized by three dimensions: knowledge complexity, knowledge uniqueness, and knowledge contribution by sharing. We find that from the perspective of knowledge sharing, only firms with complex knowledge and core knowledge will benefit from KM platforms. However, only core knowledge should be accompanied with incentives. Simple knowledge and expert knowledge should not be the target of sharing promotion.

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