# Design and Evaluation a Knowledge Management System by Using Mathematical Model of Knowledge Transfer

Kouji Aoyama, Takanori Ugai, and Jun Arima

Fujitsu Laboratories Ltd.
4-1-1 Kamiodanaka Nakaharaku Kawasakishi Kanagawa 211-8588 Japan
{aoyama.kouji, ugai, arima.jun}@jp.fujitsu.com

**Abstract.** Based on our experiences, we have proposed a mathematical model for knowledge transfer in order to make knowledge management mechanism or system take root in the organization and to obtain guidelines to make it work. We are developing a know-how sharing system designed based on the insight obtained from the proposed model. We derived and applied the two ideas as design guidelines based on the analysis using the proposed model: one is mutual reviewing to increase the sense of participation, and another is establishment of the criteria to evaluate the background information about the knowledge to be shared. In this paper, we explain the proposed mathematical model and the system design based on the model. And we describe the evaluation on the prototype system. It shows that the mathematical model could derive guidelines to make the KM system work well.

**Keywords:** knowledge management, knowledge transfer, knowledge sharing.

## 1 Introduction

In recent years Knowledge Management (KM) is getting greater and greater attention. It has become a common practice to assess corporate knowledge as a part of enterprise value. Utilization of knowledge has become important in beating the competitors. This is why KM systems have been introduced in many enterprises. However, we can find only a few successful cases. We have also experiences of failures. For example, a system could not accumulate enough volume of knowledge because of low sense of participation of users. And another system could not utilize accumulated knowledge because the users didn't understand the knowledge well enough to use it. On the other hand there is no generally effective formal KM analysis technique, which can be used 1) to judge whether the KM mechanism and system will work well before introducing them into the organization; 2) to compare different KM mechanisms; and 3) to analyze why and how it is not functioning well if an introduced KM mechanism is not working well. As a result, we have repeated similar failures.

Jun Ma, et al, [1] studied influences of organizational structure on knowledge transfer in organization and showed that knowledge transfer happens more in the

B. Apolloni et al. (Eds.): KES 2007/ WIRN 2007, Part II, LNAI 4693, pp. 1253–1260, 2007.

organization with a flat structure than in the organization with a hierarchical structure. However, their work only treats the organizational structure so it is not enough to use to analyze a KM mechanism in an organization and to compare KM mechanisms. C. Loebecke, et al. [2] established a model to show how knowledge transfer takes place in co-opetition relationship based on game theory and made some suggestions about its management. But the model explains a specific situation where the relationship is co-opetition, and the model doesn't cover the many practical enterprise situations.

In order to solve the above problems we have proposed a mathematical model for knowledge transfer [3]. The model is based on our experiences applying KM system to enterprise environment, and one of the purposes is to obtain guidelines to make a KM mechanism or system take root in the organization and to make it work well. The model shows a knowledge transfer takes place depending on the balance between profit and cost on the provider and the recipient. Furthermore, we are developing a know-how sharing system designed based on the insight obtained from the proposed model. This system is intended to promote the circulation of knowledge among system engineers (SE). We derived the following two ideas as design guidelines based on the analysis with the proposed model and applied them to the system:

1) Mutual reviewing to increase the sense of participation;
2) Establishment of the criteria to evaluate the background information about the knowledge to be shared.

In this paper, the proposed mathematical model for knowledge transfer is explained in chapter 2 and the conditions where the KM mechanism works successfully are shown based on the model. In chapter 3, we explain the system design based on the mathematical model and explain about the evaluation on the prototype system. It will show that the mathematical model could derive guidelines to make the KM system function successfully.

## 2 Mathematical Model of Knowledge Transfer

There are various methods for knowledge transfer. For instance, the methods can include written or oral reports or those employing visuals, site tours and visits, personnel rotation, education, training and standardization, etc [4]. Whatever the method used, in considering knowledge transfer, we can divide the parties involved into two sides: the side which sends the knowledge and the one which receives the knowledge. In this paper, we define knowledge transfer by separating the parties into the one which provides the knowledge (Sender) and the one which receives the provided knowledge (Receiver).

The knowledge transfer is defined as a relationship between the sender and the receiver and we introduce the profit, the cost, and the barrier as factors that influence the transfer. Specifically, they are defined as follows (Table1).

**Table 1.** Three factors concerning knowledge transfer

| | Profit | Cost | Barrier |
|---|---|---|---|
| Sender | Appreciation, reward, sense of contribution, accomplishment, satisfaction | Document creation time, explanation time, support time | Competitive relationship, level of trust, sense of uneasiness, success or failure experience, exhibitionism, sense of fellowship |
| Receiver | Improvement of work efficiency, improvement of success probability, satisfaction | Time spent in participating the meeting, conversion time | Competitive relationship, level of trust, sense of uneasiness, success or failure experience, exhibitionism, sense of fellowship |

*Profit*: Direct benefit obtained by providing and receiving knowledge. The sender's profit (Ps) includes incentives, the improvement of the sender's own skills, etc. The receiver's (Pr) profit includes improvement of work efficiency and improvement in success probability as a result of receiving the knowledge, etc.

*Cost*: Cost required for providing and receiving knowledge. The sender's cost (Cs) includes the time required for creating documents, communicating verbally, the work to provide information beneficial for the receiver, etc. The receiver's cost (Cr) includes the work to interpret or convert the received knowledge in order to use it, etc.

Contextual difference (d) is considered as a factor that greatly influences the cost. According to Ishizuka [5], there are many indications that whether the transferred knowledge can fully demonstrate its power at its destination is dependent on the context of the individuals or organizations by which the knowledge was generated. Context means the backgrounds of the knowledge, such as tacit knowledge, situation, environment, logical thread or organizational culture, etc. Therefore the cost can be regarded as an increasing function of the contextual difference between the sender and the receiver. This means the greater the contextual difference is, the more work it takes, for example, to explain in order to close the gap, hence the greater cost. For instance, if you compare the case where one tries to convey the knowledge about a sales activities in one industry sector to a member belonging to the same team with the case where one tries to convey it to a team engaged in sales activities to a different customer in a different industry sector, the latter clearly requires more explanation for knowledge transfer compared with the former.

On the other hand, when the contextual difference between a sender and a receiver is large, the profit obtained from the knowledge tends to fall in general. This is because as the contextual difference becomes larger, it becomes less likely for a situation conducive to the utilization of the knowledge to be realized. In view of this,

in this paper, we consider the profit of the receiver (Pr) as the attenuation function of the contextual difference (d) between the sender and the receiver.

Based on this model which consists of the profit and the cost, if the profit is larger than the cost, knowledge transfer will actively take place while there is likely to be little knowledge transfer if the profit is smaller than the cost. However, generally, the condition alone does not seem sufficient to promote knowledge transfer. For example, simply giving incentives to increase profit does not drive people to actively provide knowledge to others. It is suspected that a factor other than the profit and the cost is involved. In this paper, we assume the factor as the barrier and define it as follows:

*Barrier*: something that influences knowledge transfer in the relationship with others or in the environment. It can give either positive or negative influence on the motivation to provide/receive knowledge. The barriers on the sender side (Bs) include factors that affect the motivation to provide knowledge, such as the level of trust in the knowledge receiver, (competitive/cooperative) human relationship with the receiver, etc. The barriers on the receiver side (Br) include factors that affect the motivation to acquire knowledge, such as the level of trust in or preconceived notion about the knowledge provider as a result of past success/failure experiences, the availability of the search on the system, the trouble it takes to listen to the knowledge provider, etc.

McClelland[6] classified human motivation into four types: achievement, power, affiliation and avoidance motives. They are respectively included in sense of achievement (Profit), exhibitionism (Barrier), sense of fellowship (Barrier), and failure experience (Barrier), etc.

Using the three factors including seven parameters that are Ps, Cs, Bs, Pr, Cr, Br, and d, we have modeled some aspects of knowledge transfer as follows:

- Case where knowledge is offered: $Ps - Cs(d) > Bs$
- Case where knowledge is received: $Pr(d) - Cr(d) > Br$

The left-hand side is called the sender's profit/loss and the receiver's profit/loss respectively. The above expressions mean, if more profit than barrier remains after the cost is subtracted from the profit, knowledge transfer will occur. We gave a formal definition of the plus (+)/minus (-) operators and the comparison operators (<,>) in Ugai[7]. But we treat the operators in the informal intuitional manner in this paper.

## 3 Design and Evaluation of the KM System Based on the Knowledge Transfer Model

### 3.1 Outline and Assumption for the Know-How Sharing System

We are developing a know-how sharing system and the way to operate it, with the aim being to accumulate system development tips and ideas invented by SE in order to allow a SE to utilize other SE's knowledge in their own work. This system handles knowledge about project management and communication. Some of the knowledge required for system development is difficult to be broadly transferred, because the

contextual difference is large depending on the packages or in the industry sectors of the customer's business. However, we believe knowledge about project management and communication can be utilized widely and it is possible to achieve major effects by sharing such knowledge across the organization. Furthermore, even if it is possible to get general knowledge of such kind through off-the-shelf books, we believe small tips found inside the organization will prove particularly effective.

### 3.2 Derivation of Design Guidelines Based on the Mathematical Model

We consider design by applying the mathematical model to the know-how sharing system. The sender of the knowledge is a SE and the receiver of the knowledge is another SE. And, knowledge transfer is done mutually and a sender of one piece of knowledge can be a receiver of another piece of knowledge. The contextual difference (d) is large, because SE's work is different depending on industry sectors of the customers' business.

The profit for the sender (Ps) is the sense of contribution resulting from the provision of the knowledge. The cost of the sender (Cs) is the time to convey the knowledge to the recipient who has a different context, while the barrier of the sender (Bs) is a sense of uneasiness that the knowledge can end up just being thrown to the recipient. On the other hand, the profit of the receiver (Pr) is the improved work efficiency thanks to the acquired knowledge. The cost of the receiver (Cr) is the time to interpret the knowledge generated in a different context, while the barrier of the receiver (Br) is the sense of uneasiness based on the past experiences.

Based on the above, we can conclude that the knowledge sharing system has the following issues:

- Because there is a large contextual difference (d) between SE, the cost to convey the context is heavy both on the sender and the receiver sides(Cs and Cr are large).
- The barrier of the sender (Bs) and reciever (Br) are large because of the past experiences.

Because of these reasons, for the knowledge sender, it is difficult for the remainder after the cost is subtracted from the profit to be greater than the barrier (Ps-Cs<Bs) and it can be concluded that there is not likely be a lot of knowledge provision. And for the knowledge reciever, it is also difficut (Pr-Cs<Bs). So, the knowledge transfer will not occur actively.

In order to solve the issue above, we considered the following two approaches as the guidelines to lower the cost and the barrier while increasing the profit for both the sender and the reciever:

- Mutual reviewing: Mutual review method where a SE reviews the knowledge provided by other SE while contributing SE's own knowledge (tips/ideas).
- Establishment of the criteria to evaluate the context: We assume the usage of the system is that SE read accumulated knowledge, and SE discuss based on it, and improve their work or add new tips. In order to do that it is important for the description of the knowledge to be understandable just by reading. Therefore, we decided to focus on making the knowledge description graphic ("vivid") and not to require the described knowledge to be useful in practice.

### 3.3 Re-analysis with the Use of the Mathematical Model for Design Guidelines

We re-analyze the profit, cost and barrier of both the sender and receiver of knowledge in the case where the design guidelines derived from the analysis based on the mathematical model. Since the reviewer comes between the sender and the receiver of the knowledge, it can be interpreted that knowledge transfer takes place in two stages and aforementioned three factors in that case become as shown in Table 2.

**Table 2.** Three factors after the design guidelines are introduced

| | Profit | Cost | Barrier |
|---|---|---|---|
| SE (Sender) | early feedback, learning more knowledge from discussion, sense of contribution | Making a description in vivid | Sense of uneasiness about whether the knowledge will prove useful |
| reviewers | Sense of contribution | Time for reviewing | Give-and-take relationship |
| system | - | - | - |
| SE (Receiver) | Efficiency improvement | Interpreting time for knowledge | Sense of uneasiness about whether the knowledge will prove useful |

*Profit*: Mutual reviewing adds profit for sender. So, the sender's profit (Ps) includes early feedback about the knowledge through the review and learning more knowledge through discussion with the reviewer. Furthermore, the sender can get specific evaluation based on the context evaluation criteria involved in the reviewing process. On the other hands, the reviewers' profit is the sense of contribution obtained by deepening the knowledge provided by the sender through the review and the dialogue. And the receiver's profit (Pr) is greater efficiency achieved by acquiring the knowledge.

*Cost*: The sender's cost (Cs) is making a description in vivid. And the reviewers' cost includes the reviewing time spent interpreting the provided knowledge and pointing out things that are difficult for the receivers to understand. And the receiver's cost (Cr) is time of interpreting the knowledge. However, the reviewer lowered the cost by the evaluating the context, so the evaluation on the context reduces the receiver's cost (Cr).

*Barrier*: The sender's barrier (Bs) is sense of uneasiness about whether the sender's knowledge will probe useful. Regarding the barrier for the reviewer, the system of mutual review is playing a role to lower the barrier. A reviewer can also become a sender. That means there is a case that the reviewer requests the sender to review. In that sense, the sender and reviewer are in a give-and-take relationship and that serves

to motivate the reviewer to do reviewing. And the receiver's barrier (Br) is also sense of uneasiness about whether the sender's knowledge will probe useful. Regarding the sense of uneasiness on both the sender and the receiver, the mutual reviewing gives some authority to the knowledge, serving to lower the barriers on both sides. So the mutual reviewing reduces the barrier of sender (Bs) and receiver (Br).

As above, the analysis based on the mathematical model shows that the mutual reviewing mechanism plays a role to increase the profit of sender (Ps), and lower the barrier of sender (Bs), hence it is inferred that knowledge provision will be promoted (Ps-Cs>Bs). Furthermore, regarding the knowledge reception, since the reviewing process serves to lower the cost (Cr) and the barrier (Br) of the receiver, it can be reasoned that it will promote knowledge transfer (Pr-Cr>Br). Because of the above, it can be envisioned that the know-how sharing system will work successfully by introducing the two design guidelines, which are mutual reviewing and the establishment of context evaluation criteria.

### 3.4 Evaluation on the Prototype System

We evaluated the guidelines derived from the mathematical model by using as the design guideline for a prototype system of know-how sharing system. We made an evaluation experiment involving about 20 engineers for 3 month up to September 2006. The prototype system has the functions that making entries tips and ideas about system integration, selecting reviewers, making entries reviewing comment, and integrating by using Puki-Wiki.

As a result, 80 cases of tips and ideas were accumulated. The provision of knowledge was done on the trial basis without any incentives except for a request for entries only once a week and done as an activity separate from the participants' main business. Still, within 24 hours of registration of each knowledge, approximately 80% of them received feedback of 3 or more comments as a result of reviewing. Furthermore, 11 people done knowledge provision in 20 people, and 17 people reviewed. So, we consider the guidelines worked successfully.

However, in this trial, we only evaluated whether SE provided their knowledge under the experimental environment. This is because there were no opportunities to utilize the knowledge with the trial period being 3 months and the trial small in scale.

As described above, we performed analysis, using the mathematical model for knowledge transfer, on the know-how sharing system design, studied guidelines to make the KM system work successfully and conducted evaluation of the prototype. As a result, it was learned that the design guidelines derived from the mathematical model were functioning successfully for knowledge .provision. This has allowed us to demonstrate the mathematical model could derive guidelines to make the KM system function successfully.

## 4 Summary

In this paper, we described the outline of the mathematical knowledge transfer model we have proposed, explained the design and prototyping of the KM system derived from analysis based on the model, and conducted evaluation on the prototype system.

We have successfully demonstrated that it is possible to derive the design guidelines using the model and that the guidelines are valid.

In our model, knowledge transfer is defined using three factors (profit, cost and barrier). Knowledge transfer actively takes place when the remainder after subtracting the cost from the profit is greater than the barrier. Furthermore, the contextual difference between the provider and the recipient of the knowledge affects the cost and the profit on the recipient side and serves as a parameter of the knowledge transfer.

Based on the analysis with the model, we derived two operation guidelines: 1) mutual reviewing to increase the sense of participation; 2) establishment of the criteria to evaluate the background information about the knowledge to be shared. Then we evaluated a prototype system which is know-how sharing system among SE and found out that the knowledge provision was successfully performed. As a result, it is shown that the mathematical model could derive guidelines to make the KM system function successfully.

However, the trial period was relatively short and the number of involved people was small. So we could not see opportunities to utilize the knowledge in the trial. In future, we will continue to run trials based on the prototype system, continuously observe how to use the transferred knowledge. And we are also planning to evaluate the KM system involving a greater number of people. Through the evaluation of the system we will verify the design based on the mathematical model.

## References

1. Ma, J., Xi, Y., Chen, Y.: Simulate the Effect of Organization Structure on Knowledge Transfer. In: ISCIT2005 (2005)
2. Loebeck, C., Van Fenema, P.C., Powell, P.: Co-Opetition and Knowledge Transfer. DBAIS 30(2) (1999)
3. Aoyama, K., Ugai, T., Arima, J.: Mathematical model of knowledge transfer. In: National Conference of JASMIN 2006, Autumn, pp. 54–54. JSMIN (2006)
4. Garvin, D.A.: Building a Learning Organization, Diamond Harvard Business Review (March 2003)
5. Ishizuka, H.: Solutions for Knowledge Transfer Obstacles, Faculty of information and communication, Bunkyou University. Research information 33 (July 2005)
6. McClelland, D.C: Human Motivation. Cambridge University Press, Cambridge (1988)
7. Ugai, T., Aoyama, K., Arima, J.: A Mathematical Model of Knowledge Transfer and Case Studies. In: Seventh International Conference on Management (July 2007) (to be appeared)