

Article

Internal Knowledge Sharing by Infrastructure Maintenance Engineers in Small and Medium Size Construction Companies in Japan

Chika Yamasaki^{1,a,*}, Michael Henry^{2,b}, Kohei Nagai³, Koji Matsumoto³,
and Hiroshi Yokota²

¹ Graduate School of Engineering, Hokkaido University, Sapporo, Japan

² Faculty of Engineering, Hokkaido University, Sapporo, Japan

³ Institute of Industrial Science, The University of Tokyo, Tokyo, Japan

E-mail: ^achikaymsk@eis.hokudai.ac.jp (*Corresponding author), ^bmwhenry@eng.hokudai.ac.jp

Abstract. It is necessary to increase the capability of engineers to carry out maintenance management for keeping infrastructure safe and serviceable. Many regional training programs have been established to develop engineers into “maintenance experts.” While small and medium size construction companies and engineering consultants play an active role in infrastructure maintenance, they have limited human and economic resources for joining the training programs, so the sharing of knowledge acquired from the programs becomes important for improving the capability of the company as a whole. The objective of this research is to investigate how engineers who participated in regional training programs shared their knowledge inside their organization using an online questionnaire survey. It was found that leadership is an important factor for driving knowledge sharing activities, particularly for adapting the knowledge acquired from the training program to the company’s environment. However, the lack of experience serves as a barrier to the deeper transfer of knowledge, such as on-the-job training or seminars, as these methods of knowledge sharing require expert knowledge. For organizations to improve their knowledge sharing practices, it is necessary to consider the type of knowledge to be shared and the appropriate method for sharing, along with the improvement of the leadership for knowledge sharing in the organization.

Keywords: Infrastructure, maintenance management, sharing knowledge, knowledge management.

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1. Introduction

1.1. Background

Recently, the Japanese infrastructure system has begun to age rapidly, as infrastructure constructed during Japan's economic growth period begins to reach and exceed its design service life. For example, the percentage of bridges over 15 meters in length that have been in service for more than 50 years was around just 9% in 2011, but is expected to grow to more than 50% by 2031 [1]. Consequently, the need for maintenance management is increasing, and investment in technology and maintenance management systems has increased to tackle this situation.

However, it is difficult to sufficiently carry out maintenance management in local areas due to a lack of budget, skills, and human resources. The construction industry, in particular, is being affected by the increase in people retiring, especially workers of the baby-boom generation, who were born between 1947 and 1949, and have reached retirement age starting in 2007 [2]. The retirement problem is additionally compounded by the lack of a means for transferring the skills and know-how from retiring experienced workers. Consequently, maintenance management has to be carried out under these human resources limitations.

1.2. Infrastructure Maintenance Training Programs in Japan

To solve the problem of a lack of skills in local governments and construction companies, numerous maintenance manager training programs have been developed in local areas in Japan. One such program in Japan, the Maintenance Expert (ME) training program, was established by the Center for Infrastructure Asset Management Technology and Research at Gifu University in 2008. The trainees participate in a short term, intensive training curriculum for four weeks, which includes design, maintenance management, and infrastructure management. At the end of the program, they take a certification exam to become a "maintenance expert." A typical curriculum of the ME training program is given in Table 1. Gifu University has conducted the ME training program 14 times since its inception, and has produced more than 300 graduates [3].

Table 1. A typical curriculum of the ME training program [4].

Eligible person	Engineers with some experience in disaster mitigation and maintenance management
Period	80 classes over 20 days
Topics	Design of bridges and tunnels, maintenance management for bridges, soils and slopes, earth structures, pavement and river structures, infrastructure management

Such "maintenance expert" training is being conducted not only by Gifu University, but also by Yamaguchi University, Ehime University, Niigata University, and the National Institute of Technology Maizuru College. Moreover, other training programs similar to ME are also being conducted in some areas. One example is the Michimori Project, which is run by the Infrastructures Lifetime-Extending Maintenance Research Center at Nagasaki University. The Michimori Project started in 2008 and includes four courses: three are for maintenance engineers, and one is for normal citizens including non-maintenance engineers. The courses for engineers consist of three steps: the first step is inspection, the next is evaluation, and the last one is maintenance management and advanced engineering development. As of 2017, the Michimori Project has produced about 270 graduates [5, 6].

While participating in these training programs should contribute to the lack of skills in local areas, sharing of the knowledge acquired from the training program by graduates could help improve their organizations' capability to handle maintenance management. However, civil engineering knowledge includes many technical aspects, so it is not easy to fully share this knowledge with other people. To promote the sharing of maintenance management knowledge, efficient and effective methods for knowledge sharing, as well as the conditions conducive to knowledge sharing, should be clarified. This research approached this target by using knowledge management theory to study knowledge transfer and change.

1.3. Knowledge Management Theory

Knowledge management is one approach to the management of business administration for achieving organizational objectives by making the best use of knowledge. In this theory, knowledge is divided into two types in terms of the knowledge characteristics. “Explicit” knowledge is objective knowledge that can be expressed by words, figures or formulas, and it can be preserved as a database by computer processing. On the other hand, “tacit” knowledge is subjective knowledge that is based on personal feeling or experience, and it is difficult to transfer to another person by words or language alone [7].

Maintenance management knowledge includes many different categories of knowledge, such as phenomena of deterioration, inspection technologies, assessment and evaluation, prediction, countermeasures, and total asset management. Some of these knowledge are more explicit, such as manuals for operating inspection equipment and equations for calculating deterioration progress. Other knowledge types are more tacit, such as evaluation of structural quality based on visual inspection and interpretation of inspection results. Therefore, the process for sharing maintenance management knowledge should take into account the unique characteristics of the knowledge types.

The SECI model (Fig. 1) illustrates the process of changing knowledge or transferring knowledge between people or in an organization. This model was proposed by Nonaka and Takeuchi in 1996 [8]. “Socialization” is a process to transfer tacit knowledge by sharing experience, “Externalization” is a process to change from tacit knowledge to explicit knowledge by externalizing the internalized tacit knowledge, “Combination” is a process to combine various types of explicit knowledge to create new explicit knowledge, and “Internalization” is a process to develop tacit knowledge through experience.

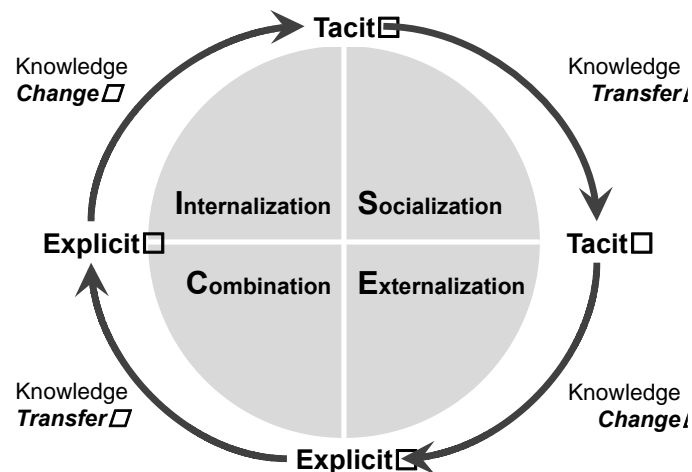


Fig. 1. SECI model for knowledge change and transfer.

In the case of this research, “Externalization” is treated as the planning and conducting of the training program, whereby the expert knowledge of the trainers related to maintenance management is made external so that it can be shared, and the trainees will receive the tacit knowledge of the experts as their own explicit knowledge. After returning to their organization, through “Combination” the program graduates will share the acquired knowledge through reports or informal communication to adapt the acquired knowledge to their specific maintenance management conditions and needs, thus creating explicit organizational knowledge. Then, this explicit knowledge is changed to tacit knowledge by using the acquired knowledge for practicing maintenance management and building experience through “Internalization.” Finally, people who have developed tacit knowledge about maintenance management through experience can transfer their tacit knowledge to other people through “Socialization,” such as OJT (On the Job Training), or externalize their tacit knowledge to create explicit knowledge through conducting seminars. This conceptual process forms the basis for investigating the sharing of knowledge acquired through the local training programs on maintenance management.

1.4. Research Objectives

This research focused on the knowledge sharing practices of maintenance engineers in small and medium size Japanese construction companies after they participated in infrastructure maintenance training programs. While small and medium size construction companies play an active role in infrastructure maintenance, these companies also have limited human and economic resources for joining the training programs, so the internal sharing of knowledge acquired from the programs becomes important for improving the capability of the companies as a whole. Using the results of a questionnaire survey on how Japanese engineers who participated in training programs shared their knowledge after returning to their organizations, the objective of this research is to clarify the knowledge sharing practices of the maintenance engineers in small and medium size construction companies, and to analyze the factors affecting whether knowledge sharing was carried out. The analysis results are then discussed using knowledge management theory, and key points for improving knowledge sharing are proposed.

2. Research Method

2.1. Data Collection

Data collection for this research was carried out using an online questionnaire survey targeted at engineers who participated in infrastructure maintenance training programs (Table 2). Seven programs cooperated by distributing the survey request to their participants: the ME programs at Gifu University, Yamaguchi University, Ehime University, Niigata University, and National Institute of Technology Maizuru College; the Michimori program at Nagasaki University; and a Regional Development Bureau training program for port facilities. Although the curricula of these programs differ in their contents, scope, etc., they all of these include infrastructure maintenance management, including practical work, so, for the purposes of this survey, it is assumed that the differences in curricula are not significant. With the support of the program administrators, a total of 337 responses were received for a response rate of 42.3%.

The questionnaire survey was designed to clarify how trainees shared the knowledge acquired from the training programs within their organization, and contained eight sections covering: (1) program participation, (2) knowledge retention, (3) knowledge sharing methods, (4) sharing environment, (5) improvement of knowledge sharing, (6) organizational characteristics, (7) organizational environment, and (8) respondent characteristics. This research focuses only on (3) knowledge sharing methods, (6) organizational characteristics, (7) organizational environment, and (8) respondent characteristics (Table 3).

Table 2. Questionnaire survey outline.

Collection method	Anonymous online questionnaire survey
Period	1 Dec. to 31 Dec., 2016
Target	Engineers who participated in infrastructure maintenance training programs from private companies (construction companies and consultants) and local regional governments.
Distribution method	Request to seven program administrators to distribute URL of questionnaire survey to program participants by e-mail
Responses	337 people (42.3% response rate)

Table 3. Questionnaire survey contents used in this research.

Section	Contents
Knowledge sharing methods	Report, seminar, OJT (On the Job Training), informal communication
Organizational characteristics	Private or public, organization scale
Organizational environment	Leadership, framework, human resources (number), human resources (quality), economic resources, IT environment
Respondent characteristics	Age, gender, educational background, maintenance experience

2.2. Total Respondent Distribution and Sample Extraction

The distribution of all respondents by organizational type and scale is shown in Table 4. Respondents from private organizations comprise roughly 57% of the sample, and represent construction companies, general contractors, and construction consultants. The majority (73%) of private organization respondents are employed by small and medium size companies. In this research, these respondents, as well as those from micro size companies, were extracted for in-depth examination, creating a research sample of 181.

Table 4. Distribution of all respondents by organization (N=337).

Type	Scale (Capital assets; number of employees)	
Public	National government	12.1%
	Prefectural government	12.7%
	Municipal or local government	17.5%
Private	Large size company (more than 3 hundred million yen; more than 300 employees)	2.9%
	Small and medium size company (less than 3 hundred million yen; between 21 and 300 employees)	41.5%
	Micro size company (20 or fewer employees)	12.1%
Other	- A few examples should be given.	1.7%

3. Survey Results and Preliminary Analysis

The survey results are divided into sample respondent characteristics, organizational environment, and methods for sharing knowledge. Based on these results, a preliminary analysis is then carried out using linear regression to clarify the factors that affect whether each knowledge sharing method was carried out.

3.1. Sample Respondent Characteristics

The respondent characteristics (age, gender, education, and maintenance experience) are shown in Table 5. 40% of the respondents fell between 41 and 50 years of age, and respondents over 40 years of age account for 66%. Nearly the entire sample was male. Respondents who graduated from university with an undergraduate degree accounted for 59% of the sample, and 52% of respondents had five or fewer years of experience with infrastructure maintenance.

3.2. Organizational Environment

The respondents evaluated whether six factors representing organizational environment (leadership, framework [a set of rules or strategies to guide decision making and improve organizational performance], number and quality of human resources, economic resources, and information technology environment) were sufficient or insufficient for carrying out knowledge sharing in their organization. The results are shown in Table 6. A majority of respondents felt that their organization has sufficient “quality of human resources”, “economic resources”, and “IT environment” for carrying out knowledge sharing, with “IT environment” shown to be the item which most respondents found to be sufficient at 72%. Conversely, “leadership,” “framework,” and “number of human resources” were felt to be insufficient by a majority of respondents, and “framework” was found to be the least sufficient of the evaluated items, with only 18% of respondents indicating it as sufficient for knowledge sharing in their organization.

3.3. Methods for knowledge sharing

The respondents’ utilization of methods for knowledge sharing inside their organizations is shown in Table 7. The most utilized method was “informal communication,” which was the only method conducted by a majority of respondents (60%), whereas “seminar” and “OJT” were the least-utilized methods (28% and 20%, respectively). “Report” (41%) was more utilized relative to “seminar” and “OJT,” but was still only utilized by a minority of respondents.

Table 5. Respondent characteristics for micro, small and medium size construction companies (N=181).

Age	
21~30 years	6.1%
31~40 years	28.2%
41~50 years	40.3%
51~60 years	18.8%
61 years or older	6.6%
Gender	
Male	97.2%
Female	2.8%
Education	
High school degree, equivalent, or lower	17.7%
Technical school or junior college degree	13.3%
University undergraduate degree	59.1%
University graduate degree (Master)	9.9%
Maintenance experience	
0~5 years	52.5%
6~10 years	24.9%
11~15 years	13.3%
16~20 years	2.8%
21 years or more	6.6%

Table 6. Sufficiency of organizational environment factors, (N=181).

Factor	Leadership	Framework	Number human res.	Quality human res.	Economic resources	IT environ.
Sufficient	39.8%	18.2%	43.1%	53.6%	57.5%	71.8%
Insufficient	60.2%	81.8%	56.9%	46.4%	42.5%	28.2%

Table 7. Methods utilized for sharing knowledge (N=181).

Method	Report	Seminar	OJT	Informal comm.
Utilized	41.4%	19.9%	28.2%	60.2%
Not utilized	58.6%	80.1%	71.8%	39.8%

3.4. Regression Analysis

To examine the factors affecting the utilization of the knowledge sharing methods, linear regression was conducted using the organizational environment and individual characteristics factors as independent variables. Prior to the regression analysis, Pearson coefficients of correlation were calculated to clarify the relationship between the independent variables (Table 8). It can be seen that there is a relatively stronger positive correlation between "number of human resources" and "quality of human resources," "leadership" and "framework," and "age" and "years of experience." In addition, "leadership" also correlates somewhat strongly with all other organizational environment factors.

Table 9 summarizes the linear regression analysis results for each of the knowledge sharing methods. The "coefficient" indicates the normalized strength of a factor within each model, and the "significance" indicates the probability that the factor's influence is by chance. The null hypothesis – that the influence is by chance – is rejected when the significance is below 0.05, or 5%. For "report," the regression model shows that "leadership," "age," and "maintenance experience" are all significant factors for the utilization of "report" for knowledge sharing, with sufficient "leadership" as the strongest prediction factor. "Leadership" is also a significant and strongest factor for "seminar," for which "maintenance experience" is also significant. For "OJT," the only significant factor was "years of experience," which had a positive relationship with the utilization of "OJT." However, the strength of "leadership" as a predicting factor was the same as that of

“years of experience,” but it was not found to be significant. Finally, the regression model for “informal communication” shows that “leadership” is the only significant factor for this method, but the lack of a sufficient “framework” is equally strong as “leadership” for predicting the utilization of “informal communication,” even though the result is not significant.

Table 8. Correlation analysis of organizational environment and individual characteristics factors.

Factors	Organizational environment					Individual characteristics				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Organizational Environment	(1) Leadership	1.00								
	(2) Framework	0.49	1.00							
	(3) No. human resources	0.20	0.05	1.00						
	(4) Qual. human resources	0.24	0.10	0.54	1.00					
	(5) Economic resources	0.22	0.09	0.25	0.27	1.00				
	(6) IT environment	0.21	0.20	0.22	0.11	0.28	1.00			
Individ. char.	(7) Age	0.00	-0.08	-0.01	-0.11	-0.02	-0.05	1.00		
	(8) Gender	-0.00	-0.10	0.15	0.18	-0.01	-0.11	0.14	1.00	
	(9) Education	-0.00	-0.09	0.03	0.07	-0.07	0.02	-0.07	0.19	1.00
	(10) Maintenance exp.	0.14	0.02	0.04	-0.11	0.02	0.02	0.34	0.01	0.06

Table 9. Regression analysis of organizational environment and individual characteristic factors as predictors of knowledge sharing method utilization.

Factors			Report	Seminar	OJT	Informal Comm.
Organizational Environment	Leadership	Coeff.	0.179	0.198	0.110	0.207
		Sig.	0.044 *	0.004 **	0.175	0.020 *
	Framework	Coeff.	0.004	0.094	0.039	-0.208
		Sig.	0.970	0.260	0.693	0.056
	No. human resources	Coeff.	0.081	0.110	0.004	0.037
		Sig.	0.361	0.109	0.951	0.673
Qual. human resources	Coeff.	-0.048	-0.100	0.060	0.072	
	Sig.	0.588	0.152	0.464	0.422	
Economic resources	Coeff.	-0.035	0.005	-0.023	-0.062	
	Sig.	0.654	0.933	0.742	0.431	
IT environment	Coeff.	-0.113	0.055	0.046	0.128	
	Sig.	0.191	0.408	0.559	0.138	
Individual characteristics	Age	Coeff.	-0.044	-0.027	-0.009	-0.013
		Sig.	0.040 *	0.102	0.635	0.539
	Gender	Coeff.	-0.115	0.078	-0.136	-0.288
		Sig.	0.618	0.664	0.519	0.216
Education	Coeff.	-0.035	0.001	0.006	0.022	
	Sig.	0.208	0.953	0.815	0.418	
Maintenance exp.	Coeff.	0.097	0.073	0.103	0.043	
	Sig.	0.004 **	0.005 **	0.000 ***	0.201	

Significance codes: 0 *** 0.001 ** 0.01 * 0.05

From this analysis, it was clarified that “leadership” is a commonly shared strong factor across all four knowledge sharing methods, and that “maintenance experience” is a strong factor for “report,” “seminar,” and “OJT.” Both “leadership” and “maintenance experience” are also significant factors for several methods. While both factors play an important part in driving knowledge sharing after participation in training programs, “leadership,” as an organizational factor, may be improved through organizational effort and investment in training, education, and so forth, whereas “maintenance experience” can only be increased

through actual practice carrying out maintenance of infrastructure. Therefore, in the secondary analysis, the role of leadership and its effect on knowledge sharing will be described and examined in greater detail.

4. Secondary Analysis on the Effect of Organizational Leadership

Preliminary analysis of the survey results clarified that leadership is an important factor for determining whether respondents shared knowledge acquired from training programs in their organization. The objective of the secondary analysis is to explore how leadership affects knowledge sharing by separating the sample respondents into two groups depending on the leadership for knowledge sharing in their organization, and analyzing the differences in organizational environment and utilization of knowledge sharing methods.

4.1. The Role of Leadership in Knowledge Sharing

In this research, leadership in an organization is defined as the establishment of a visual and clear strategy for sharing knowledge. A leader is essential for building leadership in an organization, but a “leader will have to show a willingness to share information and knowledge freely and to seek it from others in the organization” [9]. To improve leadership for knowledge sharing, first a leader should be appointed. The leader will then have to demonstrate a willingness and efficiency to share knowledge within the organization, particularly because there may be resistance to knowledge sharing due to reasons such as a lack of trust. Leadership is not an easy organizational trait to improve, but the value of investing in it may be clarified by examining how knowledge sharing differs between organizations with and without leadership.

4.2. Comparison of Organizational Environment and Knowledge Sharing Methods Depending on Leadership

The respondents were divided into two groups depending on whether their organization has sufficient leadership or not for knowledge sharing, and the individual characteristics, organizational environment, and utilization of knowledge sharing methods were compared between the two groups. Based on the results in Table 5, 72 respondents stated that their organizations had sufficient leadership, compared to 109 respondents who stated that their organization had insufficient leadership. For individual characteristics, there was no notable difference between the two groups. However, a distinct difference can be seen in the environment (Table 10) and utilization of knowledge sharing methods (Table 11). For the organizational environment, the P-values for all chi-square tests were highly significant, which confirms that all organizational factors have a dependency on leadership. The difference due to leadership was particularly large for “framework,” as the sufficiency of “framework” increased by 39% when sufficient leadership was present. This results shows that an organization that has sufficient leadership also has other sufficient organizational environment factors for sharing knowledge, as was previously suggested by the correlation analysis in Table 7.

Table 10. Comparison of the sufficiency of organizational environmental factors for knowledge sharing.

Factors	Framework	Number human res.	Quality human res.	Economic resources	IT environ.
Sufficient leadership (n=72)	41.7%	55.6%	68.1%	70.8%	83.3%
Insufficient leadership (n=109)	2.8%	34.9%	44.0%	48.6%	64.2%
Chi ² P-value	0.000***	0.006**	0.002**	0.003**	0.005**

Significance codes: 0 *** 0.001 ** 0.01 * 0.05

When examining the effect of leadership on the utilization of knowledge sharing methods, it can be seen that having sufficient leadership leads to an increase in the utilization rate for all methods, and this difference is significant in all cases. The largest increase (27%) due to sufficient leadership can be seen in the case of “seminar.”

Table 11. Comparison of the utilization rate of knowledge sharing methods.

Method	Report	Seminar	OJT	Informal comm.
Sufficient leadership (n=72)	52.8%	36.1%	38.9%	70.8%
Insufficient leadership (n=109)	33.9%	9.2%	21.1%	53.2%
Chi ² P-value	0.011*	0.000***	0.009**	0.017*

Significance codes: 0 *** 0.001 ** 0.01 * 0.05

4.3. Regression Analysis Depending on Leadership

Linear regression analysis was again carried out, but this time to examine how factors other than leadership affect knowledge sharing in environments where leadership is sufficient or insufficient. Table 12 shows the result of regression analysis modeling the utilization of the four knowledge sharing methods for respondents who belong to an organization with sufficient leadership. The factors that have high significance are “number of human resource,” “age,” and “maintenance experience” for “report,” and “framework” for “informal communication.” No significant factors could be identified for “seminar” and “OJT.” Therefore, when an organization has sufficient leadership, the utilization of “report” and “informal communication” may be affected by the previously-mentioned significant factors. For example, the utilization of “informal communication” should increase in an environment with sufficient leadership but an insufficient “framework” for conducting knowledge sharing.

Table 12. Regression analysis of knowledge sharing method utilization with sufficient leadership.

Factors		Report	Seminar	OJT	Informal Comm.	
Organizational environment	Framework	z Sig.	-0.034 0.766	0.107 0.374	-0.038 0.759	-0.318 0.005 **
	No. human resources	z Sig.	0.347 0.020 *	0.154 0.311	0.224 0.161	0.099 0.099
	Qual. human resources	z Sig.	-0.229 0.150	0.311 0.164	-0.158 0.358	0.030 0.838
	Economic resources	z Sig.	0.013 0.920	0.013 0.919	-0.021 0.881	-0.129 0.310
	IT environment	z Sig.	-0.268 0.106	-0.004 0.983	-0.019 0.910	0.310 0.598
	Individual characteristics	Age	z Sig.	-0.071 0.050 *	-0.044 0.231	-0.016 0.679
Gender		z Sig.	-0.343 0.356	0.111 0.773	-0.068 0.864	-0.347 0.329
Education		z Sig.	-0.058 0.218	-0.052 0.293	-0.02 0.692	0.011 0.795
Maintenance exp.		z Sig.	0.135 0.012 *	0.069 0.206	0.047 0.411	0.031 0.536

Significance codes: 0 *** 0.001 ** 0.01 * 0.05

On the other hand, Table 13 shows the result of regression analysis for respondents who belong to an organization with insufficient leadership. “Maintenance experience” is a common strong predicting factor for “seminar” and “OJT,” and the significance is high, too, in both cases. The utilization of “OJT” is also very strongly and significantly affected by “framework.” While there are few significant results, it can be said that increasing “maintenance experience” is important for conducting knowledge sharing in organizations with insufficient leadership.

Table 13. Regression analysis of knowledge sharing method utilization with insufficient leadership.

Factors			Report	Seminar	OJT	Informal Comm.
Organizational environment	Framework	z	0.363	0.001	0.559	0.540
		Sig.	0.239	0.996	0.025 *	0.095
	No. human resources	z	-0.062	0.113	-0.077	0.047
		Sig.	0.595	0.102	0.411	0.697
	Qual. human resources	z	0.042	-0.045	0.133	0.071
		Sig.	0.706	0.486	0.140	0.542
Economic resources	z	-0.078	-0.013	-0.012	-0.032	
	Sig.	0.436	0.814	0.872	0.757	
IT environment	z	-0.081	0.053	0.029	0.115	
	Sig.	0.434	0.386	0.722	0.291	
Individual characteristics	Age	z	-0.035	-0.022	-0.011	-0.007
		Sig.	0.217	0.190	0.619	0.811
	Gender	z	0.150	0.077	0.004	-0.018
		Sig.	0.626	0.669	0.988	0.953
	Education	z	-0.020	0.028	0.020	0.031
		Sig.	0.562	0.182	0.472	0.409
Maintenance exp.	z	0.052	0.066	0.135	0.061	
	Sig.	0.244	0.013 *	0.000 ***	0.195	

Significance codes: 0 *** 0.001 ** 0.01 * 0.05

5. Discussion

5.1. Barriers to Knowledge Sharing Based on Knowledge Management Theory

The results of the analysis were applied to the SECI model based on knowledge management theory (Fig. 2). In this research, externalization that changes the tacit knowledge of the maintenance training program experts to the explicit knowledge of the program graduates is the planning and carrying out of the training program. After taking the training, graduates are between externalization and combination, which is where the internal knowledge sharing process will begin after they return to their organization. Through combination, explicit knowledge is transferred through sharing methods such as report or informal communication inside the organization, because these methods can use words and characters for expressing the knowledge. Next, the graduates and other people who belong to the organization have to study and apply the knowledge acquired by training and shared in practical situation in order to change their maintenance management knowledge from explicit to tacit knowledge. This process is internalization. Finally, people who have become highly skilled can transfer their tacit knowledge directly to others inside organization by OJT, which is a process of socialization, or change it into explicit knowledge through seminar, which is similar to the original process for sharing the expert knowledge by the training programs. The socialization process by OJT is particularly effective for transferring tacit knowledge because the transferor's feelings and experience can be directly shared in this process.

The survey result clarified that report and informal communication – combination processes for transferring explicit knowledge – are relatively more conducted, but OJT and seminar – socialization and externalization processes for transferring tacit knowledge and changing tacit to explicit knowledge, respectively – are less conducted. Moreover, the important factors for sharing knowledge are leadership in report, seminar and informal communication, and years of experience in seminar and OJT. Consequently, it can be said that leadership is important for combination, and studying and building experience (internalization) are important for socialization and externalization. Furthermore, analysis showed that organizations that do not have leadership have very low utilization of seminar and OJT, which are important for the long-term capability of the organization to carry out maintenance management.

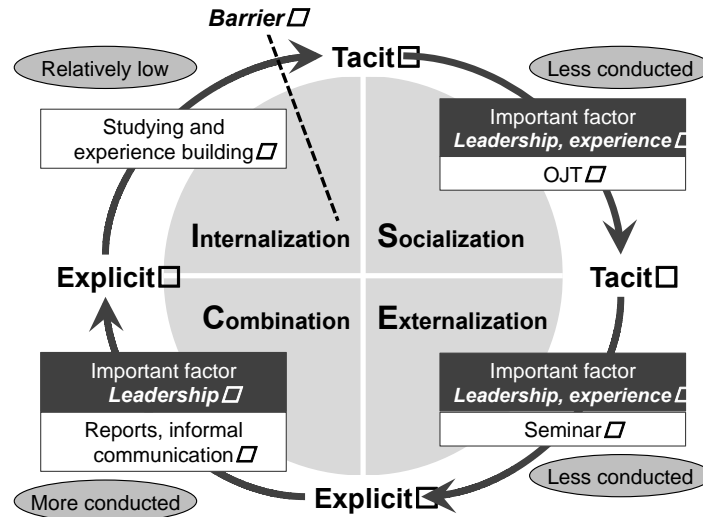


Fig. 2. SECI model with investigation result.

Therefore, the first barrier to conducting knowledge sharing inside an organization is the leadership capacity. Without that, the knowledge acquired from the training programs cannot be adapted to the organization's situation, making it difficult to proceed to actual practice and experience building. Even in the case of informal communication, this type of knowledge sharing may not provide long-term results for the organization itself, as the sharing of knowledge via informal communication does not preserve the knowledge in a written form, as will be discussed later.

If sufficient leadership is present in the organization, then this creates an environment in which knowledge sharing is encouraged, and people will have the opportunity to put into practice the knowledge transferred to the organization from the training programs through actual maintenance management of infrastructure. In addition, leadership was shown to positively correlate with all other organizational environment factors, suggesting that improving leadership generates other benefits within an organization as well. However, the maintenance experience of the survey respondents is relatively low overall, regardless of leadership, which implies that many people have yet to turn the explicit organizational knowledge into their tacit knowledge. This is the second, and larger, barrier to knowledge sharing, as both experience and leadership are important factors for utilizing OJT and seminars to further transfer or change maintenance management knowledge. Since the level of maintenance experience is relatively low, these two methods are not widely carried out, even in an organization with sufficient leadership. Since leadership does not correlate with maintenance experience, it has to be assumed that outside factors, such as the economic investment for maintenance management, is also playing a powerful role in limiting the ability of the small and medium construction companies to share and develop their maintenance management knowledge.

5.2. Implications for Improving Knowledge Sharing

Before suggesting ways to improve knowledge sharing in the organizations, the precise characteristics of the four methods should be clarified, as there may be optimal means to apply each method. The advantages and disadvantages of each method are shown in Table 14. For knowledge combination, both report and informal communication are easy to conduct, but difficult to transfer tacit knowledge. Furthermore, report is one-way communication but can preserve knowledge on paper or as data, whereas informal communication is two-way communication but does not leave any detailed record of the knowledge itself or its transfer. For socialization and externalization, both seminar and OJT can transfer tacit knowledge and enable two-way communication, but are more difficult to conduct, as they require depth of tacit knowledge, and OJT requires the ability to have access to an actual site for carrying out the training.

The type of knowledge types and the objective of the knowledge sharing should decide the proper method. If the knowledge can be used as explicit knowledge, then report may be the proper method, and informal communication may serve as a supplementary method. In order to better utilize these methods, however, the companies have to improve leadership for sharing knowledge to encourage the utilization of

these two methods, since it was shown from the survey that leadership is an important factor for explicit knowledge transfer by combination.

Table 14. Advantages and disadvantages of each knowledge sharing method.

Method	Advantages	Disadvantages
Report	<ul style="list-style-type: none"> • Easier to conduct • Can preserve as paper or data 	<ul style="list-style-type: none"> • Difficult to transfer tacit knowledge • One-way communication
Seminar	<ul style="list-style-type: none"> • Can transfer tacit and explicit knowledge • Can use many tools • Two-way communication 	<ul style="list-style-type: none"> • More difficult to conduct
OJT	<ul style="list-style-type: none"> • Can transfer tacit and explicit knowledge • Can share feeling and experience • Two-way communication 	<ul style="list-style-type: none"> • Limited to practical site • Cannot transfer to many people simultaneously
Informal communication	<ul style="list-style-type: none"> • Easy to conduct • Two-way communication • Can conduct anywhere 	<ul style="list-style-type: none"> • Difficult to transfer tacit knowledge • Limitation to the amount of transferable knowledge • Difficult to preserve knowledge

On the other hand, if transfer or change of tacit knowledge is the objective, then seminar and OJT are the proper methods. Seminar is more appropriate when the tacit knowledge acquired needs to be shared with a large group of people, but this will result in the change of tacit to explicit knowledge, so there are some limitations to this method. When the knowledge to be transferred is high level tacit knowledge at the small scale, OJT is the more optimal method. Both seminar and OJT, however, require the engineers who are sharing the knowledge to have a high level of experience and deep tacit knowledge, so building experience from explicit knowledge via internalization is necessary. The survey showed that many companies do not share knowledge by seminar and OJT, which may be due to the lack of opportunities to internalize the explicit knowledge through practice. Therefore, while leadership for improving knowledge sharing is an important first step, building experience through practice is essential to fully develop the knowledge acquired from training programs into the organization's tacit knowledge resources.

6. Summary

Knowledge sharing can be an important activity for improving the capability of small and medium size construction companies. This survey showed that leadership is an important factor for driving knowledge sharing activities in an organization, particularly for adapting the explicit knowledge from training programs to the organization's environment to create new explicit organization knowledge. It was shown that the next step, building practical experience using the acquired knowledge, is necessary to develop individual tacit knowledge from the explicit organizational knowledge. Since this step is still not frequently carried out, it is a barrier to the changing or transfer of tacit knowledge into other knowledge types, such as by OJT and seminars. Reviewing the utilization of the knowledge sharing methods and their advantages and disadvantages in the context of knowledge management shows that organizations have to choose the proper method for sharing knowledge within their organization, considering the knowledge type and whether knowledge change or transfer, when considering effective knowledge sharing.

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References

- [1] Ministry of Land, Infrastructure, *Transport and Tourism, Actual State of Road Structure—Bridge*. 2017. Available: https://www.mlit.go.jp/road/didaku/yobohozen/yobo1_1.pdf [Accessed: 5 October 2017]
- [2] Ministry of Health, Labor and Welfare, *Annual Report on Health, Labor and Welfare 2008-2009*. 2008, ch. 2, pp. 46,
- [3] K. Sawada, “What can be done in local university—Infrastructure maintenance expert developing,” *Journal of Japan Society of Civil Engineers*, vol. 101, no. 12, pp. 24-25, 2017.
- [4] (2017). *Center for Infrastructure Asset Management Technology and Research* [Online]. Available: <http://ciam.xsrv.jp/> [Accessed 12 October 2017]
- [5] K. Takahashi, H. Matsuda, and M. Ikeda, “Training engineers who have a role in maintenance management of road by industry-government-academia cooperation,” *Monthly Publication of Japan Road Association*, vol. 906, pp. 2-5, 2016.
- [6] Infrastructures Lifetime Extending Maintenance Research Center, “Michishirube,” vol. 22, pp. 3, 2015.
- [7] M. Nakauchi, “Promotional factor on knowledge transfer in engineers,” *Histochemistry*, vol. 48, no. 2, pp. 61-73, 2014.
- [8] I. Nonaka and H. Takeuchi, *The Knowledge Creating Company*. Toyo Keizai Inc., 1996.
- [9] S. C. Goh, “Managing Effective Knowledge Transfer: an integrative framework and some practice implications,” *Journal of Knowledge Management*, vol. 6, no. 1, pp. 23-30, June, 2001.