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Assessment of safety management information systems for general contractors

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Abstract

The purpose of this paper is to propose a methodology that evaluates safety management information systems (SMIS) for general contractors mainly in terms of managerial effectiveness. Characteristics and variables of safety management assessments were investigated first, and several assessment techniques were then developed. A single index system measuring safety management performance of projects is also proposed for practical application. The assessments of safety management tasks are performed by several different variables including measures, project lifecycle, organization, etc. The assessment result from a case-company shows that a limited number of safety tasks can effectively represent the overall safety performance of a project. Among these tasks, managing the "daily safety meeting minutes" through the information systems was found to be the most important task. Details and implications of a case are outlined.

Keywords: Information systems; Methodology; Performance measurement; Planning; Safety

1. Introduction

Safety is a critical measure for successful construction projects, and general contractors are vigorously utilizing safety management information systems (SMIS) to effectively

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improve their safety performance. However, there has been no systematic and quantitative effort to evaluate comprehensive appropriateness of SMIS for construction organizations. In this context, the purpose of this paper is to propose a methodology that evaluates SMIS for general contractors mainly in terms of managerial effectiveness. This paper consists of two phases where the first part is a development of the methodology and the second part is a test of this methodology by using a case-company.

Characteristics and variables of safety management assessments were investigated first in this paper. The major variables for evaluating safety control tasks include the 'importance within a safety management procedure', 'importance as a consequential impact', 'frequency of occurrence', 'user satisfaction' and so forth. Several assessment techniques using a set of questionnaires and a series of workshops were developed. A single index system measuring safety management performance of construction projects was also proposed for practical application.

By applying the proposed methodology to a case-company, the safety management tasks were classified and listed under a hierarchy, and each task was evaluated based on the pre-defined variables. 'As-is' as well as 'to-be' systems were separately analyzed so as to clearly identify the areas to be improved. Details and implications of the case are outlined. Practical issues and lessons learned are briefly discussed as well.

For the purpose of clarifying the research objectives and identifying issues to be addressed in this study, research questions can be described as follows: (1) What are the most 'important safety tasks' those can enhance the overall safety performance of an organization with optimized managerial effort? (2) How can the head office safety experts or managers 'monitor and support each project', in terms of safety control, according to priority? Is there any indicator for this priority? (3) How can an organization develop 'safety management information systems' in order to meet these requirements?

2. Integrated perspective of safety management systems

The general role of information systems (IS) has changed in organizations. The traditional role of IS had been to support business functions by replacing labor-intensive transactions. However, as the use of information systems has become widespread and deeply integrated with business processes, the role has expanded to include support for or even shaping of corporate strategy (Bakos and Treacy, 1986; Jung and Gibson, 1999; Jung et al., 2004). Therefore, the assessment process of safety information systems should incorporate the 'comprehensiveness of IS related issues' and the distinct 'characteristics of the construction safety tasks' as well.

The information systems assessment (ISA) issues in the construction industry were discussed in several studies as summarized in Table 1, all of which stressed the uniqueness of the construction industry. Betts (1995) developed a five-level conceptual framework for strategic IS from an '*industry-level perspective*'. The five levels include the national construction industry, professional institutions, construction enterprises, construction projects, and construction products. Stewart and Mohamed (2004) and Jung et al. (2004) developed two independent 'comprehensive and detailed frameworks' from the industry-level perspective by analyzing the survey responses from general contractors. Even though the research objectives and measures are different, these two studies commonly attempted to quantitatively evaluate the major factors affecting effective IT utilization in the industry.

Table 1
Variables for ISA in construction

Research	Level	Variables	Measures	Remarks
Betts (1995)	Industry	National construction industry Professional institutions Construction enterprise Construction projects Construction products	Not applicable	Conceptual framework
Jung et al. (2004)	Industry	Infrastructure Utilization Support	33 measures Integrated single index	Statistical analysis for level of informatization
Stewart and Mohamed (2004)	Industry	Operational perspective Benefits perspective Strategic competitiveness perspective Technology/system perspective User orientation perspective	25 measures	Statistical analysis of factors for IS evaluation
Jung and Gibson (1999)	Company	Corporate strategy Management Computer systems Information technology Incremental investment	5 procedures integrated single index	Assessment methodology for strategic IS planning
Peña-Mora et al. (1999)	Project	Environmental scan IT diffusion Internal scrutiny IT investment modeling	Not applicable	Conceptual framework for strategic IT planning
Jung et al. (2004)	Domain	Frequency Explicitness Organizationality Importance	9 measures integrated indices	Assessment methodology for strategic IS planning
This study	Biz function	Role and responsibility Specific characteristics Degree of Importance Utilization	10 measures integrated single index	Assessment methodology for strategic IS planning

In their development of an IS planning methodology from a '*company-level perspective*', Jung and Gibson (1999) firstly proposed a quantitative assessment methodology that incorporated comprehensive issues of IS planning for construction organizations. Five measurement categories by Jung and Gibson (1999) are corporate strategy, management, computer systems, information technology, and incremental investment.

Peña-Mora et al. (1999) point out another aspect, which is the temporary project organization, composed of multiple firms on a '*project-level perspective*'. These variables give a meaningful point of departure for organizing IS categories in the construction industry. Their framework for IT planning includes ''environmental scan, IT diffusion, internal scrutiny, and IT investment modeling.

Based on the study by Jung and Gibson (1999), further into a '*domain-level perspective*', Jung et al. (2006) developed an ISA methodology for strategic knowledge management

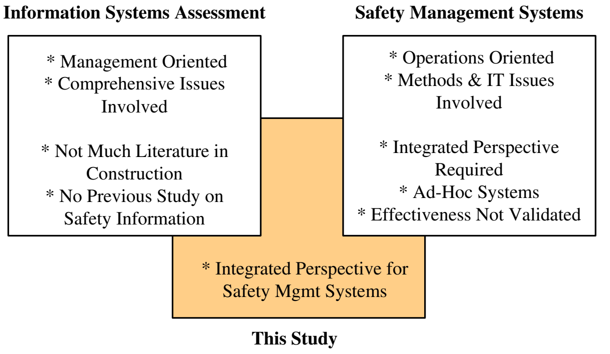

Fig. 1. Research scope and uniqueness.

planning where the strategic fit and disseminative fit of knowledge areas were the two major concerns for evaluating.

Previous studies in the area of SMIS propose techniques and methodologies for effective utilization of IT. Four major categories of SMIS studies include Critical Path Method (CPM) based safety evaluation and control (Kartam, 1997; Wang et al., 2005), reuse of historical safety database and knowledge (Chua and Goh, 2004), hazard evaluation of work types (Go et al., 2005), and visualized design-for-safety-tools (Hadikusumo and Rowlinson, 2002; Hadikusumo and Rowlinson, 2004). Even though the studies significantly contribute to the body of SMIS, there has been no systematic effort in literature to comprehensively evaluate the safety management information systems (SMIS) from a '*business function-level perspective*'.

In summary, the 'information systems assessment (ISA)' usually addresses comprehensive issues while the 'safety management systems' most often deals with operational methods or IT issues for safety control. It is also noteworthy that there has been no previous research regarding overall evaluation of information systems for safety management. In this context, as described in the research objectives before mentioned, this study focuses on the 'information systems assessment' of 'safety management systems (ISA)'. Table 1 illustrates how different variables and measures can be used for different level of perspectives. This table also supports in validating the variables identified in this study with broader perspectives of ISA in construction (see Fig. 1).

By combining these two research topics, this study aims to systematically measure the managerial effectiveness of safety management tasks in the information systems, incorporating the comprehensive issues from a business function-level perspective within an organization-wide business process.

3. Safety management information systems assessment

Assessing information systems for an organization requires comprehensive measures including "corporate strategy, management, computer systems, information technology, and incremental investment" (Jung and Gibson, 1999) as described in Table 1. However, the information systems assessment (ISA) for SMIS in this study is a process from a 'business function-level perspective'. In order to clarify the research scope, it is assumed that the 'corporate-level issues' of ISA such as 'strategic fit', 'incremental investment', and others have already been analyzed and decided. Thus, this study emphasizes the managerial effectiveness of the business function of safety management. However, it is strongly recommended to analyze the overall systems requirement from a company-level perspective, as described in Jung and Gibson (1999), before evaluating the SMIS of an organization.

3.1. Assessment variables and measures

In order to effectively identify the most 'important safety tasks' as an information systems module, this study proposed four major variables for the assessment including 'roles and responsibilities', 'characteristics of tasks', 'importance', and 'utilization'. These four variables are further divided into 10 measures. These ten assessment measures for SMIS include 'position in charge', 'compulsoriness', 'frequency', 'transaction type', 'data type', 'workload', 'managerial importance', 'impacting importance', 'degree of utilization', and 'user satisfaction', as described in Table 2.

The measure of 'position in charge' is to analyze the roles and responsibilities of the system users. The use of this measure enables us to analyze the intra- and inter-organizational distribution of safety tasks in an effective manner. Second group including 'compulsoriness', 'frequency', 'transaction type', 'data type', 'workload' is to specify the characteristics of each task in SMIS. These measures of 'characteristics of tasks' variable provide with supportive rationale for prioritizing managerial significance as daily activities. The measures of 'managerial importance' and 'impacting importance' in the 'importance' variable are the key assessment measures for prioritizing the tasks. The former indicates the importance as a business process itself among the entire procedure, while the latter implies the managerial impact that the result of a task may have (Jung et al., 2006). Finally, 'degree of utilization' and 'user satisfaction' are to identify areas to be improved.

It is noteworthy that Kjellén (2000) pointed out the feedback mechanism as an essential variable of safety information systems. The feedback feature and the feedback time of experiences can be critical factors for decision supporting process to prevent accidents (Kjellén, 2000). The 'feedback feature' would be good variable for some SMIS on a domain level. In other words, specific subsystems of SMIS may heavily require a domain-level perspective (Jung et al., 2006). However, every subsystem of the SMIS may not require the feedback feature as a critical measure. The feedback time is partly considered as a criterion for safety management index (SMI) in this study. The details for SMI are described in the following section.

3.2. Safety management index

Every safety task in the SMIS must be important, the relative importance of selected tasks can represent the overall performance of a construction project. In order to effectively monitor and evaluate the performance of safety management tasks, a single index based on selected measures is proposed in this study. The performance of each safety task in the SMIS is evaluated by two criteria; the 'timeliness' and 'completeness'. Based on these concepts, the safety management index (SMI) is defined as follows:

$$\mathrm{SMI} = T_1 * C_1 * W_1 + T_2 * C_2 * W_2 + T_3 * C_3 * W_3 + \ldots\ldots + T_n * C_n * W_n, \tag{1}$$

where T = timeliness, C = completeness, W = weighting, n = selected safety tasks in SMIS.

Table 2
Information systems assessment cases and variables

Measure	Value	# of Tasks (case-study)	% of Tasks (case-study)
Position in charge (P)	1. Construction engineer (CE)	–	–
	2. Project engineer (PE)	–	–
	3. Safety engineer (SE)	7 (SE)/27 (SE/SM/PD)	50.00
	4. Project director at H/O (PD)	1 (SE/SM/PD)	1.47
	5. Safety manager at H/O (SM)	6 (SM)/27 (SE/SM/PD)	48.53
Compulsoriness (C)	1. Compulsory (CO)	17	42.50
	2. Optional (OP)	23	57.50
Frequency (F)	1. Once per month	6	15.00
	2. Twice per month	7	17.50
	3. Four times per month	1	2.50
	4. 15 times per month	1	2.50
	5. Above15 times per month	19	47.50
	6. Once per year	1	2.50
	7. Once per project	5	12.50
Transaction type (T)	1. Official announcements (OA)	7	17.50
	2. On-line references (OR)	5	12.50
	3. Data & status query (DQ)	9	22.50
	4. Data & status entry (DE)	2	5.00
	5. Data query & entry (DE/DQ)	12	30.00
	6. Report upload (RE)	5	12.50
Data type (D)	1. Structured (ST)	22	55.00
	2. Unstructured (UNST)	18	45.00
Workload (W)	1. Less than one hour per transaction	35	87.50
	2. One to four hours per transaction	–	–
	3. Less than one day per transaction	–	–
	4. More than one day per transaction	4	10.00
	5. Not applicable (e.g. on-line lecture)	1	2.50
Importance-mgmt (IM)	1. Low	7	17.50
	2. Medium	14	35.00
	3. High	19	47.50
Importance-impact (II)	1. Low	18	45.00
	2. Medium	18	45.00
	3. High	4	10.00
Degree of utilization (UD)	1. Low	5	12.50
	2. Medium	11	27.50
	3. High	24	60.00
User satisfaction (US)	1. Very low (above 21)	7	17.50
	2. Low (16–20)	5	12.50
	3. Medium (11–15)	5	12.50
	4. High (6–10)	8	20.00
	5. Very high (under 5)	8	20.00
	6. Not applicable (e.g. planned systems)	7	17.50

The major purpose of using this SMI is to monitor the managerial performance of each construction project for a company. In other words, the head office can provide with appropriate support to the job sites depending on its performance that can be determined by the SMI. By doing this, an organization can effectively prevent possible accidents those are at least due to managerial defectiveness. Details for both the measures and SMI are further illustrated in the next chapter by using a case.

4. Case-study

In order to examine the viability, the measures and methodology proposed in this study was applied to a case-company, which is one of the largest general contractors in South Korea. A series of workshops and a set of questionnaires were used in 2005 to gather the data from the head office and job sites.

The participants in this case include the researchers as a consultant and a facilitator, the head office safety managers as the appraiser, information systems managers as the informant, and job site safety engineers as the active users. The researchers provided the methodologies and guided the entire process in order to keep the integrity. The head office safety managers played a critical role in the assessment process, because they exactly know the corporate-wide safety concerns of case-company. A series of workshops were held for this assessment process, and the researchers filled out the evaluation forms by discussing the contents of SMIS tasks with the head office safety managers. The job site safety engineers also evaluated the measure of 'impacting importance' and 'user satisfaction' for forty tasks through a questionnaire. The result from this survey is described in the last three columns in Table 3.

The first step was to list the safety management tasks in the company's information systems. Fifty-nine current tasks were identified by listing major menus of existing SMIS of the case-company. Three new tasks were added into the list as the case-company was planning new SMIS tasks. The list of 62 tasks were then shuffled and reorganized into 40 tasks within 8 categories by balancing the level of managerial significance. Table 3 shows the full list of reorganized 40 SMIS tasks and 8 categories analyzed in this study.

4.1. SMIS assessment by measures

Each task of the SMIS of the case-company was evaluated by head office safety managers according to the predefined assessment measures. Each of ten measures for forty SMIS tasks was evaluated through several workshops. Even though the values for each measure were predefined as shown in Table 2, sometimes it was not easy for the respondents to choose an appropriate one among the given values due to subjectivity. Researchers provided definitions and explanation in order to secure adequate objectivity throughout the evaluation process.

For the measure of '*position in charge* (*P*)', as depicted in Tables 2 and 3, it is found that 50% of the tasks are designed for field operations, and the rest for head office management. It is also found that no task is currently integrated with the sub-contractor's information systems. Therefore, it is strongly recommend by the researchers to expand and share the roles and responsibilities through the SMIS.

As the characteristics of the SMIS tasks, 17 out of 40 tasks are compulsory ones by the company's policy (*compulsoriness* (*C*)). 47.5% of the tasks require more than 15 transactions per month (*frequency* (*F*)). 52.5% of the tasks are only for retrieving information

Table 3
SMIS assessment summary (case-company)

Code	Description	P	C	F	T	D	W	IM	II	UD	US	Weighting	
A	*Safety info and references*												
A1	General announcements	SE/SM	OP	1/MO	OA	UNST	1	M	M	H	VH	31	4.81%
A2	Safety mgmt process by regulations	SE/SM	OP	2/MO	OA	UNST	1	H	H	H	H	44	6.82%
A3	Safety and health news	SM	OP	Above 15/MO	OA	ST	1	M	M	H	VH	27	4.19%
A4	Safety mgmt forms	SE/SM	OP	2/MO	OA	UNST	1	L	L	M	H	33	5.12%
A5	Insurance and legal information	SM	OP	2/MO	OA	UNST	1	L	L	H	H	21	3.26%
A6	Local references	SE/SM	CO	1/MO	DE/DQ	UNST	1	L	M	H	L	10	1.55%
A7	Online Q&A	SE/SM	OP	Above 15/MO	DE/DQ	UNST	1	M	H	H	N/A	N/A	N/A
B	*Project information*												
B1	Project outlines	SE/SM	CO	Above 15/MO	DQ	ST	1	L	L	M	H	4	0.62%
B2	Monthly plan and status report	SE/SM	CO	1/MO	DE/DQ	ST	1	M	M	H	VL	15	2.33%
B3	Monthly plan and status report (H/O)	SM	OP	Above 15/MO	DQ	ST	1	L	M	M	N/A	N/A	N/A
B4	Weekly plan report	SE/SM	CO	4/MO	DE/DQ	ST	1	M	M	H	N/A	N/A	N/A
B5	Daily safety meeting minutes	SE/SM	CO	Above 15/MO	DE/DQ	ST	1	H	H	H	N/A	N/A	N/A
B6	Pledge of safety engineer	SE/SM	CO	1/PJT	DE/DQ	ST	1	L	L	L	VL	0	0.00%
C	*Project safety database (plan and reference)*												
C1	Project safety and health mgmt plan	SE	CO	1/PJT	RE	UNST	4	M	M	H	VH	38	5.89%
C2	Project safety risk mgmt plan	SE	CO	1/PJT	RE	UNST	4	M	M	H	VH	37	5.74%

C3	Process manual by constr. activities	SE	CO	2/MO	RE	UNST	4	M	H	H	L	44	6.82%
C4	Best practice – project cases	SE	OP	2/MO	DE/DQ	UNST	1	M	L	H	H	42	6.51%
C5	HIGH-FIVE activity	SE	CO	1/PJT	RE	UNST	1	L	M	H	L	1	0.16%
C6	Historical DB by constr. activities	SE/SM	CO	1/MO	DE/DQ	ST	1	M	M	H	N/A	N/A	N/A
D	*Accident reporting*												
D1	Investigation report	SE/SM	OP	Above 15/MO	DQ	ST	1	L	M	M	VH	8	1.24%
D2	Accident report submission	SM	CO	2/MO	DE	ST	1	M	M	H	N/A	N/A	N/A
D3	Accident news flash	SM	OP	Above 15/MO	DQ	ST	1	M	L	H	VH	35	5.43%
D4	Accident status report (general)	SE/SM	OP	Above 15/MO	DQ	ST	1	M	M	H	VL	7	1.09%
D5	Accident history mgmt	SE/SM	OP	2/MO	DE/DQ	ST	1	L	L	M	VL	10	1.55%
D6	Accident statistics	SE/SM	OP	Above 15/MO	DQ	ST	1	L	L	H	VL	55	8.53%
E	*Safety patrol*												
E1	Site visit plan by H/O	SM	CO	1/PJT	RE	ST	1	M	M	H	VH	14	2.17%
E2	Safety patrol report	SE/SM/PD	CO	Above 15/MO	DE	ST	1	M	M	H	VL	17	2.64%
E3	Safety patrol report query	SE/SM	OP	Above 15/MO	DQ	ST	1	M	M	H	VH	20	3.10%
E4	Monthly safety inspection	SE/SM	CO	1/MO	DE/DQ	ST	1	M	L	M	M	14	2.17%
F	*Zero accident activity*												
F1	Zero accident status report	SE/SM	OP	1/MO	DQ	ST	1	L	L	L	L	1	0.16%
F2	Safety incentives	SE/SM	CO	1/MO	DE/DQ	ST	1	M	M	H	N/A	N/A	N/A
G	*Safety education and instruction*												
G1	Online safety lectures	SE/SM	OP	Above 15/MO	OR	ST	N/A	M	L	M	H	10	1.55%
G2	Education status (general)	SE	CO	1/YEAR	DE/DQ	UNST	1	L	L	M	H	2	0.31%

(*continued on next page*)

Table 3 (*continued*)

Code	Description	P	C	F	T	D	W	IM	II	UD	US	Weighting	
G3	Education status (individual)	SE	OP	Above 15/MO	DQ	ST	1	L	L	L	M	1	0.16%
G4	Education materials by work sections	SE/SM	OP	Above 15/MO	OA	UNST	4	M	M	H	M	57	8.84%
G5	Audio–visual materials	SE/SM	OP	Above 15/MO	OA	UNST	1	L	L	M	M	19	2.95%
H	*Site links*												
H1	Safety related sites	SE/SM	OP	Above 15/MO	OR	UNST	1	L	L	L	H	5	0.78%
H2	Safety equipment and materials	SE/SM	OP	Above 15/MO	OR	UNST	1	L	L	L	VL	5	0.78%
H3	Safety info by constr. companies	SE/SM	OP	Above 15/MO	OR	UNST	1	L	L	M	M	6	0.93%
H4	Accident cases	SE/SM	OP	Above 15/MO	OR	UNST	1	L	L	M	L	12	1.86%

The measures and their predefined values are listed in Table 2. Refer to Table 2 for full descriptions for the abbreviations.

without submitting any data or reports (*transaction type* (*T*)). 55% have structured data (*data type* (*D*)), 87.5% take less than on hour per transaction (*workload* (*W*)).

Degree of importance in two different aspects was measured. 19 out of 40 tasks scored high for the '*managerial importance* (*IM*)', while only 4 tasks including 'safety management process by regulations (A2)', 'online Q&A (A7)', 'weekly plan report (B4)', and 'process manual by construction activities (C3)' were selected as being high for the measure of '*impacting importance* (*II*)'.

'*Degree of utilization (UD)*' and '*user satisfaction (US)*' were also measured in order to identity areas to improve the SMIS. Although a separate questionnaire was sent out to job site safety engineers to score the importance of SMIS tasks from their perspective, the result was only used as valuable references for many purposes (see Fig. 1).

As depicted in Table 3 and Fig. 2, four tasks including 'safety management process by regulations (A2)', 'daily safety meeting minutes (B5)', 'online Q&A (A7)', and 'process manual by construction activities (C3)' were found to be the most important modules in terms of the 'importance' variable.

4.2. SMI index

Though case specific to this study, it is found that the timeliness and completeness of six major safety tasks can effectively represent the overall safety performance of a project within the case-company. The conditions for selecting candidates for SMI components were; (1) compulsory (compulsoriness measure) , (2) at least once per month (frequency measure), (3) data entry or report upload (transaction type measure), (4) not by head office (position in charge measure), and (5) high importance (importance measure). The selecting process is illustrated in Fig. 3.

The rationale behind having these selecting criteria for SMI components is to easily monitor the job site safety performance. For example, if a task's transaction type is 'data & status query' in Table 2, it would be extremely hard to measure the degree how the project engineers appropriately use the queried data for safety controls. However, if it is a

L (18)	**M (20)**	**H (2)**	**IM / II**
L-H (0) -	**M-H (2)** A7, ***C3***	**H-H (2)** A2, ***B5***	**H (4)**
L-M (4) A6, B3, C5, D1	**M-M (14)** A1, A3, ***B2, B4***, C1, C2, ***C6***, D2, D4, E1, E2, E3, ***F2***, G4	**H-M (0)** -	**M (18)**
L-L (14) A4, A5, B1, B6, D5, D6, F1, G2, G3, G5, H1, H2, H3, H4	**M-L (4)** C4, D3, E4, G1	**H-L (0)** -	**L (18)**

Fig. 2. Importance matrix for SMIS (case-company).

Code	P	C	F	T	IM	II
B2	SE/SM	CO	1/MO	DE/DQ	M	M
B4	SE/SM	CO	4/MO	DE/DQ	M	M
B5	SE/SM	CO	Above 15/MO	DE/DQ	H	H
C3	SE	CO	2/MO	RE	M	H
C6	SE/SM	CO	1/MO	DE/DQ	M	M
F2	SE/SM	CO	1/MO	DE/DQ	M	M
	Not by H/O	*Compulsory*	*At least once per month*	*Data entry or report upload*	*High importance*	

Fig. 3. Importance matrix for SMIS (case-company).

data entry or report upload, the head office can easily determine the timeliness and completeness of the safety tasks through the SMIS.

'Daily safety meeting minutes (B5), 'process manual by construction activity (C3)', 'monthly plan and status report (B2)', 'weekly plan report (B4)' , 'historical DB by construction activities (C6)', and 'safety incentives (F2)' were chosen as being the SMI components. Therefore, the SMI for the case-company can be described as shown in formula (2).

$$\mathrm{SMI} = T_{\mathrm{B2}} * C_{\mathrm{B2}} * W_{\mathrm{B2}} + T_{\mathrm{B4}} * C_{\mathrm{B4}} * W_{\mathrm{B4}} + T_{\mathrm{B5}} * C_{\mathrm{B5}} * W_{\mathrm{B5}} + T_{\mathrm{C3}} * C_{\mathrm{C3}} * W_{\mathrm{C3}} + T_{\mathrm{C6}} * C_{\mathrm{C6}} * W_{\mathrm{C6}} + T_{\mathrm{F2}} * C_{\mathrm{F2}} * W_{\mathrm{F2}}, \qquad (2)$$

where T = timeliness; 1.0 – on time, 0.8 – delayed less than 2 days, 0.6 – delayed longer than 2 days, C = completeness; 1.0 – above average, 0.8 – average, 0.6 – below average, W = weighting; relative weightings among these six components can be used (see Table 2). Weightings are not used in this case. For the purpose of having the weighting, this study asked the safety engineers on the job site the importance of each task. The result is represented in the form of percentile score in the last column of Table 3. Relative weightings of the six SMI component tasks can be used in the formula (2).

In this SMI formula, the scores for timeliness (T) are relatively clear while the scores for completeness (C) are somewhat subjective (i.e. above or below average). However, it is almost impossible and also unnecessary to have a detailed list for evaluation scores for forty different tasks listed in Table 3. It is more effective to grade each transaction by the expert judgment in the head office, because this index is a corporate-wide performance indicator that monitors possibly several hundred projects at the same time.

The SMI can provide with a monthly performance index of each project incorporating these six selected components of tasks. It effectively represents the overall soundness of safety control process performed through its in-house information systems.

The six components have 'less than one hour per transaction' workload except the 'process manual by construction activities (C3)' that requires a report upload. Nevertheless, it may require additional management overhead in order to timely have all the information for these six components, from several hundred job sites of the case-company. One of the most important features for performance measurement system is to avoid excessive overhead effort to collect and maintain detailed data for analysis (Jung and Woo, 2004).

Therefore, the researchers suggest the use of recent information technology, especially data acquisition technologies (DATs) including GPS, barcode, RFID, and so on, in order to automatically collect daily occurring job site data and to automatically fill out the forms for SMI components. Again, using these technologies requires an integrated approach. In other words, the data should be used not only for the SMI but also for progress measurement, payroll, materials management, scheduling, and so forth (Jung and Kang, 2007), which makes the DATs deployment more viable in terms of alleviating workload as well as systemizing the performance controls in SMIS.

5. Conclusions

An assessment methodology for safety management information systems (SMIS) proposed in this study has been proved to be effective enough to provide a construction organization with meaningful insights for identifying improvement areas with priority. The authors feel that the proposed methodology is also universally applicable to any organizations in the construction industry including owners, construction managers, engineers, or contractors regardless of their size or discipline. This universal application can be easily performed by simply adjusting the values for each measure in Table 2 in order to fit the characteristics of an organization.

This study fully addressed the three research questions mentioned in introduction. "The most important safety tasks" can be assessed by using the four variables (roles and responsibility, specific characteristics, degree of importance, and utilization) and ten measure proposed in this study. The method to prioritize for the purpose of monitoring and supporting projects (the second research question) is using a single index that is composed of the most important safety tasks. The timeliness and completeness of each task are used as criteria for prioritizing the projects. Finally, for the third research question, the assessment methodology proposed in this study can provide with meaningful insights to improve the safety information systems for an organization as described above.

Keeping records and regularly analyzing the performance indices for safety management can greatly contribute to reduce and prevent the accidents in construction. In order to make this process viable, key performance should be identified, and the entire monitoring process needs to be computerized. The methodology proposed in this study provides a tool to meet these requirements as well.

It is also inferred that general contractors tend to expand their safety issues further into the design phase, and that roles and responsibilities would be widely shared by project participants including designer, contractor, and subcontractors. Therefore, integrating safety information systems among different project participants would be one of the challenging issues in SMIS.

Finally, it is strongly recommended to analyze the overall requirements of safety management systems among the whole information systems in an organization as illustrated by Jung and Gibson (1999). This result from the 'company-level perspective' may affect the SMIS assessment process, even though the 'safety' is not less company-specific issue than the other construction business functions are.

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