Tool for Assessing Safety Performance of Construction Projects: Simplified Leading Indicator Approach

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Abstract

Accidents are common in all sectors, but the construction sector has the largest number of accidents. As far as the construction industry in Thailand is concerned, the work at the construction site in Thailand is subjected to a high number of accidents due to high work-related risk rates. Thailand's relatively enormous and stable economic growth has led to a rapid expansion in the influx of unskilled workers into the construction sector over the past few decades, especially in major cities. The objectives of this study are to develop a safety performance assessment tool and to collect data from medium and large construction projects based on a questionnaire tool that has been developed. The key performance indicators (KPI) were used to develop the performance assessment tool and questionnaire from the list of leading indicators. Lastly, the paper showed the result of the level of the safety performance of the construction companies in Thailand. Generally, three of the safety performance were in a poor level, namely preplanning risk assessment, emergency response system, and safety reward and incentive.

***Keywords**: Safety Performance, Accidents, Key Performance Indicators, Leading Indicator.*

1. Introduction

In general, the laborers are often exposed to many potential health hazards such as silica, asbestos, organic dust, and other toxic chemicals in their workplace environment. Accidents are common in all industries, but the construction industry has the highest number of accidents. For example, the mortality rate in the United States construction is 15.2 per 100,000 laborers, while the manufacturing industry is 4.2 (Vedder & Carey, 2005).

The laborers in Thailand construction are exposed to high risk due to the high rates of work-related accidents (Chongsuvivatwong et al, 1998). In Thailand, the total number of employed laborers is 34.5 million persons. The total workforce in construction is about 1.4 million laborers, which are 8% of the total. According to the Ministry of Labour (2005), the statistics of deaths and injuries in all industries indicate that the rate of accidents and mortalities in the Thailand construction industry is reported as the highest of all industries (Chongsuvivatwong et al, 1998). In 2003, the construction in Thailand accounted for the total number of 787 deaths at work or 14% and the total number of 17 cases of permanent disability or 24%, which placed the construction in Thailand on the top list of the most hazardous work sector (Chongsuvivatwong et al, 1998). The Ministry of Labour in Thailand revealed that construction laborers are five times more likely to suffer from permanent disability than other industry workers.

The problems and difficulties encountered in implementing site safety schemes in Construction Company in Hong Kong (Poon, Tang, & Wong, 2008) include the tight schedule of projects, limited budget on safety investment, inefficient communication due to many subcontracting systems, unskilled and inexperienced workers, the inability of safety officers to enforce safety regulations, transient nature of construction laborers, use of alcohol, excessive hours of work for construction laborers, and insufficient penalty for not following safety regulations.

Hereby, the objectives of this study are to develop a safety performance assessment tool and to collect data from medium and large construction companies such as low-rise housing, high-rise condominium, hospital, hotel, Bangkok Mass Transit System (BTS), and Mass Rapid Transit (MRT) based on the developed tool of questionnaires. The performance assessment tool and questionnaire are developed from the list of leading Key Performance Indicators (KPI). Lastly, the paper demonstrates the level of the safety performance of construction projects in Thailand.

1.1. Safety Performance Assessment and Key Performance Indicator (KPI)

A key reason for undertaking KPI (Fernie, Leiringer, & Thorpe, 2006) is to develop intervention strategies that help reduce future workplace fatalities and injuries; therefore, it is essential that safety can be measured. Generally, safety performance has been measured by lagging safety indicators (Hinze, Thurman, & Wehle, 2013). Lagging indicators are measured after the accident or injury has occurred. Lagging indicators normally used by Occupational Safety and Health Administration (OSHA) include Days Away or Transfer (DART) injury rate, the Experience Modification Rating (EMR), Recordable Injury Rate (RIR), Restricted Work and workers' compensation (Hinze et al., 2013).

The Construction Industry Institute (CII) funded research– CII Research Report 284-11 reported that the use of leading indicators has an effective construction safety program that aims to make zero injuries in reality (Hallowell, Hinze, Baud, & Wehle, 2013). Similar components are reported in other sources (Rajendran & Gambatese, 2009; Rajendran, 2013). The leading indicators included safety recognition and rewards, accident/incident investigations, demonstrated management commitment, safety education and training, staffing for safety, pre-project and pre-task planning, employee involvement, and subcontractor management

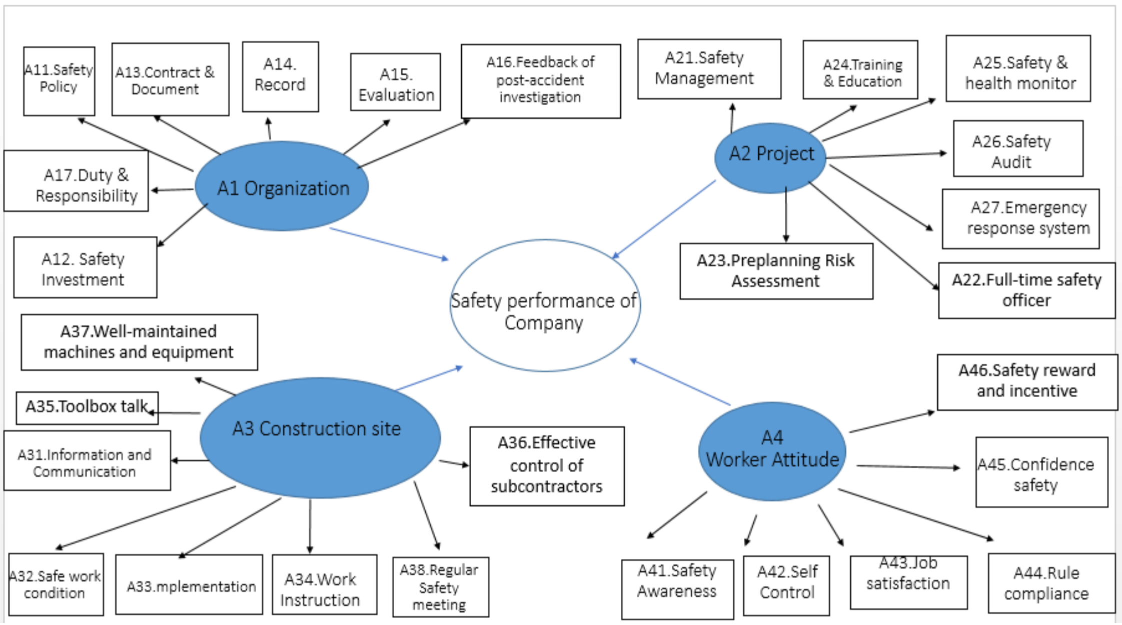

Figure 1 Safety performance assessment based on leading indicator approach.

Safety performance defined as "Overall performance of the organization safety management system in safe operation'' is the most common definition (Hsu et al., 2013). The past studies on safety performance evaluation have provided the theoretical and practical guidance for building up the frame of possible indicators. The level of the safety performance of the construction industry is mainly influenced by the following four levels: Organization Level, Project Level, Construction Site Level, and Worker Attitude Level (Ng, Cheng, & Skitmore, 2005). After an intensive review of the previous studies and researches, several sub-factors were identified and grouped accordingly. Figure 1 shows the factors related to the Organization Level A1, which consists of (A11) Safety Policy, (A12) Safety Investment, (A13) Contract and Document (A14) Safety Record, (A15) Evaluation and (A16) Feedback of Post-Accident Investigation, and (A17) Duty and Responsibility. Factors related to Project Level A2 include (A21) Safety Management, (A22) Full-Time

Safety Officer, (A23) Preplanning Risk Assessment, (A24) Induction Training and Education, (A25) Safety and Health Monitor, (A26) Safety Audit, and (A27) Emergency Response System. Factors related to Construction Site Level A3 are (A31) Information and Communication, (A32) Safe Work Conditions, (A33) Implementation, (A34) Work Instruction, (A35) Toolbox Talk, (A36) Effective Control of Subcontractor, (A37) Well-Maintained Machines and Equipment, and (A38) Regular Safety Meeting. Lastly, factors related to Worker Attitude A4 are (A41) Safety Awareness, (A42) Self-Control, (A43) Job Satisfaction, (A44) Rule Compliance (A45) Confidence Safety, and (A46) Safety Award and Incentive. In conclusion, there are 7 factors at the organization level, 7 factors at the project level, 8 factors at the construction site level, and 6 factors at the worker attitude level, summing up to 28 factors.

2. Objectives

The objectives of this study are as followed;

1) To develop a safety performance assessment tool and analyze the safety performance of construction projects

2) To collect data from medium and large construction projects such as low-rise housing, high-rise condominium, hospital, hotel, Bangkok Mass Transit System (BTS), and Mass Rapid Transit (MRT) based on the developed tool of questionnaires.

3. Materials and Methods

After identifying 28 sub-factors and grouping them into 4 main levels, a semi-closed-ended questionnaire was developed to show the level of safety implementation of a company. The respondents of the research were focused only on safety officers or persons responsible for safety work in a construction site or an organization with at least 3 years of working experience. According to the record of the Ministry of Labor of Thailand on 31st January 2020, there are 288 registered safety officers working in Bangkok. The sample calculation using the Creative Research Systems (2001) formula showed one hundred sixty-five (165) safety officers from different projects as the sample size of this study. Of these 165 projects, 76 were from medium-size projects and 89 were from large-size projects. The safety-related personals were asked to determine the current safety performance level of their organization in terms of the availability, quality of documentation and measures, the level of implementation, and frequency of updating or revision. To analyze the leading safety performance of construction, the scales of measurement below are used and the detailed descriptions are explained as follows.

Table 1 Detailed descriptions of leading safety performance used in the survey

Definition of the level of availability of the safety document	
Yes =	It is applied when the factor is available.
No =	The factor is not available.
Definition of the level of quality of documentation and implementation	
Very low =	The quality of details, work instruction, quality manual, quality plan, procedures, and records of the documentation and measures are very low.
Poor =	The quality of details, work instruction, quality manual, quality plan, procedures, and records of the documentation and measures are poor.
Average =	The quality of details, work instruction, quality manual, quality plan, procedures, and records of the documentation and measures are average.
Good =	The quality of details, work instruction, quality manual, quality plan, procedures, and records of the documentation and measures are good.
Excellent =	The quality of details, work instruction, quality manual, quality plan, procedures, and records of the documentation and measures are excellent.
Definition of the level of Implementation in the organization	
Party (0-33.9 %) =	The component is implemented only in some parts of the company (0-33.9%).
Mostly (34-67.9%) =	The component is implemented in most parts of the company (34-67.9% of the company).

Definition of the level of availability of the safety document	
Fully (68-100%) =	The component is fully implemented in all parts of the company (68-100%)
Definition of the level of frequency of updating or revision	
Never =	The document/plan/evaluation/training had never been updated or revised.
Annually =	The document/plan/evaluation/training had been updated or revised annually.
2-3 years =	The document/plan/evaluation/training had been updated or revised 2-3years ago.

The research location is Bangkok and its vicinity since Bangkok city has several types of construction and has the highest number of construction projects in Thailand. Also, Bangkok has the highest rate of accidents in Thailand, according to the Ministry of Labor of Thailand. Both private and public projects with both medium and large-scale construction projects are to be studied in this research. The collected project data were from buildings like low-rise housings, condominiums, hospitals, hotels, railways, and highways. According to the Ministry of Industry's definition, a project is considered as "medium" when its total project cost ranges between 20 million Baht and 100 million Baht with a total workforce of 50-200 workers and it is considered as "large" when total project cost is greater than 100 million Baht with a workforce greater than 200 workers (Kulchartchai, & Hadikusumo, 2010). Thus, any projects that fit into the above definition will be studied in this research.

Analysis of the result will be shown in the level of the safety performance of each factor. The weighted average formula (1) will be used to calculate the weight of each factor. Then, the weight of the factor will be used to determine the performance level being excellent, good, average, or poor. To get the numerical result for level, the scores are summed up. The scores in availabilities are yes=1 and no=0, in quality of documents and implementation (very low=0.2, low=0.4, average=0.6, good=0.80, and excellent=1), level of implementation (not at all=0, partly=0.33, mostly=0.66, and fully=1) and in the frequency of updating (never=0, daily=1, weekly=0.8, monthly=0.6, annually=0.4, and 2-3 years=0.2). The numerical analysis for the excellent level is done by summing up the highest score of 4. For the good level, it is the sum of 1+0.8+0.66+0.8=3.26; for the average level, it is 1+0.6+0.66+0.6=2.8; and, for the poor level, it is 1+0.4+0.33+0.4=2.13

$$W=\frac{\sum_{i=1}^{n=1}(Wi \times Xi)}{\sum_{i=1}^{n} N} \qquad (1)$$

Where:

W	=	weight average
N	=	number of terms to be averaged
Wi	=	weights applied to x values and
Xi	=	data values to be averaged.

4. Results and Discussion

The reliability of the entire survey is measured by Cronbach's alpha for internal consistency to verify that the grouping is valid and consistent and to create new composite variables for the categories with sufficient validity. Table 2 shows the results of the Cronbach's alpha analysis by SPSS. The result of the Cronbach's alpha is greater than 0.8, meaning that the consistency and reliability of the whole survey are sufficient. Table 2 also shows the use of Cronbach's alpha to measure the reliability of the questions within categories of the survey and to determine that the internal consistency is acceptable, and the grouping/categorization done by reviewing the literature is reliable. Since Cronbach's alpha turned out to be greater than 0.6 for each level, thus the reliability is confirmed. Further analyses are done in the following sections.

Table 2 Reliability measures for entire survey and each category

Level of Safety Performance	Description	Cronbach's Alpha
Entire Survey	(A11) to (A46)	0.906
A1 Organization Level	(A11) to (A17)	0.812
A2 Project Level	(A21) to (A27)	0.712
A3 Construction Site Level	(A31) to (A38)	0.747
A4 Worker Attitude Level	(A41) to (A46)	0.745

Table 3 shows the level of the safety performance of each indicator proposed by this research collected from 165 Thai construction companies located in Bangkok and its vicinity. The levels of safety performance are labeled as good=4-3.266, average= 3.266-2.866, and poor = 2.866-2.13.

At the organization level, (A11) Safety record and (A15) Evaluation are at the level of good performance, while the rest of the factors were at an average level. With the average weight calculated, the (A12) Safety investment was the lowest at 0.952 in terms of availability. For the quality of documents and implementation, the feedback of (A16) Post-accident investigation was the lowest at 0.758 while the (A11) Safety policy was the highest at 0.888. (A12) Safety investment was also the lowest in terms of the level of implementation in the organization at 0.692. In the frequency of updating/revision, the (A13) Contract and document were the lowest with the weight of 0.396.

For the project level, (A21) Safety management, (A22) Full-time safety officer, and (A24) Induction training and education were in good level performance. (A25) Safety and health monitoring were at an average level. In terms of availability, (A23) Preplanning risk assessment has the lowest weight average with 0.891 while the rest of the factors were 1. The weight of the (A27) Emergency response system was the lowest in terms of quality of documents and implementation. (A23) Preplanning risk assessment was also the lowest in terms of the level of implementation in an organization at 0.596 while the availability of the (A22) Full-time safety officer was the highest at 0.844. Regarding the frequency of updating/revision, (A27) Emergency response system was the lowest at 0.447. Thus, it makes the performance level of the (A23) Pre-planning risk assessment and (A27) Emergency Response System in the project level the poor performance level.

For construction site level, most of the safety factors are at the level of good performance except (A36) Effective Control of Subcontractor and (A37) Well-Maintained Machines and Equipment being in the average level. The (A38) Regular Safety Meeting was the lowest in terms of availability with an average weight of 0.994 while the rest of the factors were 1. (A34) Work Instruction was the lowest with an average weight of 0.776 in terms of quality of documents and implementation. For the level of implementation in an organization, the (A36) Effective Control of Subcontractors was the lowest at 0.705 in weight average. In terms of frequency of updating/revision, (A37) Well-Maintained Machines and Equipment were the lowest with an average weight of 0.590.

At worker attitude level, (A44) Rule Compliance was at an average level of safety performance. With an average weight calculated, the (A46) Safety Reward and Incentives were the lowest in terms of availability at 0.824, Quality of Documents and Implementation at 0.621, level of Implementation in Organization at 0.529, and Frequency of Updating/Revision at 0.419. Thus, (A46) Safety Reward and Incentives were at the level of poor performance while the rest of the factors were at a good level of performance.

Additionally, the performance of each level computed with the average number of organization level, project level, and worker attitude was in the average level while construction site at a good level of safety performance.

Table 3 Safety Performance Level of construction projects in Thailand

		Availability	Quality of Documents and implementation	Level of implementation in organization	Frequency of updating/ Revision	Total	Performance level
A1.Organization Level	A11. Safety Policy	1.000	0.888	0.820	0.444	3.152	Average
	A12.Safety Investment	0.952	0.785	0.692	0.450	2.878	Average
	A13. Contract and Document	0.994	0.834	0.807	0.396	3.031	Average
	A14. Safety Record	1.000	0.806	0.851	0.673	3.329	Good
	A15. Evaluation	1.000	0.818	0.828	0.617	3.263	Good
	A16.Feedback of post-accident investigation	1.000	0.758	0.796	0.593	3.146	Average
	A17.Duty and responsibility	1.000	0.887	0.824	0.531	3.242	Average
	Average	0.991	0.815	0.799	0.529	3.133	Average
A2.Project Level	A21.Safety Management System	1.000	0.863	0.790	0.639	3.292	Good
	A22.Full-time safety officer	1.000	0.873	0.844	0.624	3.341	Good
	A23.Preplanning Risk Assessment	0.891	0.739	0.596	0.503	2.729	Poor
	A24.Induction Training and Education	1.000	0.897	0.758	0.594	3.248	Good
	A25.Safety and health monitoring	1.000	0.836	0.802	0.548	3.186	Average
	A26.Safety Audit	1.000	0.844	0.818	0.514	3.176	Average
	A27.Emergency Response System	1.000	0.713	0.683	0.447	2.843	Poor
	Average	0.984	0.823	0.756	0.553	3.117	Average

		Availability	Quality of Documents and implementation	Level of implementation in organization	Frequency of updating/ Revision	Total	Performance level
A3.Construction site level	A31.Information and communication	1.000	0.818	0.776	0.749	3.343	Good
	A32.Safe Work Conditions	1.000	0.847	0.842	0.655	3.344	Good
	A33.Implementation	1.000	0.838	0.796	0.715	3.349	Good
	A34.Work Instruction	1.000	0.776	0.798	0.798	3.371	Good
	A35.Toolbox Talk	1.000	0.868	0.814	0.806	3.488	Good
	A36.Effective Control of Subcontractors	1.000	0.792	0.705	0.707	3.203	Average
	A37.Well-maintained Machines and equipment	1.000	0.890	0.778	0.590	3.258	Average
	A38.Regular Safety Meeting	0.994	0.879	0.809	0.712	3.394	Good
	Average	0.999	0.838	0.790	0.716	3.344	Average
A4.Worker Attitude level	A41.Safety Awareness	0.994	0.799	0.778	0.751	3.322	Good
	A42.Self-Control	0.994	0.844	0.803	0.800	3.441	Good
	A43.Job Satisfaction	0.994	0.856	0.795	0.678	3.323	Good
	A44.Rule Compliance	1.000	0.832	0.792	0.664	3.288	Average
	A45.Confidence Safety	0.994	0.816	0.772	0.752	3.335	Good
	A46.Safety Reward and Incentive	0.824	0.621	0.529	0.419	2.393	Poor
	Average	0.967	0.794	0.745	0.678	3.184	Average

Remark: ☐ Average level ☐ Good level ■ Poor level

Tables 4 and 5 show the safety performance levels of large and medium construction companies. Medium project means that its total project cost ranged between 20 million and 100 million Baht and large project means that total project cost was greater than 100 million Baht. As demonstrated in Table 4, in large construction, the poor performances were (A23) Preplanning Risk Assessment, (A27) Emergency Response System, and (A46) Safety Reward and Incentive. Furthermore, (A36) Effective Control of Subcontractors in construction site level should be highlighted. In Table 5, five poor safety performance levels were found in medium projects: (A12) Safety Investment, (A23) Preplanning Risk Assessment, (A26) Safety Audit, (A27) Emergency Response System, and (A46) Safety Reward and Incentive.

Table 4 Safety Performance level of large construction projects

		Availability	Quality of Documents and implementation	Level of implementation in organization	Frequency of updating/ Revision	Total	Performance level
A1. Organization level	A11.Safety Policy	1.000	0.930	0.854	0.445	3.229	Average
	A12.Safety Investment	1.000	0.787	0.742	0.452	2.980	Average
	A13.Contract and Document	1.000	0.829	0.843	0.420	3.092	Average
	A14.Safety Record	1.000	0.784	0.895	0.690	3.369	Good
	A15.Evaluation	1.000	0.755	0.861	0.604	3.221	Average
	A16.Feedback of post-accident investigation	1.000	0.843	0.850	0.578	3.271	Good
	A17.Duty and responsibility	1.000	0.908	0.865	0.530	3.303	Good
A2. Project level	A21.Safety Management System	1.000	0.897	0.813	0.636	3.345	Good
	A22.Full-time safety officer	1.000	0.956	0.925	0.638	3.519	Good
	A23.Preplanning Risk Assessment	0.933	0.731	0.639	0.496	2.798	Poor
	A24.Induction Training and Education	1.000	0.929	0.858	0.618	3.405	Good
	A25.Safety and health monitoring	1.000	0.827	0.824	0.535	3.186	Average
	A26.Safety Audit	1.000	0.899	0.940	0.602	3.441	Good
	A27.Emergency Response System	1.000	0.690	0.697	0.449	2.836	Poor

		Availability	Quality of Documents and implementation	Level of implementation in organization	Frequency of updating/ Revision	Total	Performance level
A3. Construction Site level	A31.Information and communication	1.000	0.802	0.768	0.748	3.318	Good
	A32.Safe Work Conditions	1.000	0.816	0.861	0.665	3.342	Good
	A33.Implementation	1.000	0.852	0.809	0.701	3.362	Good
	A34.Work Instruction	1.000	0.798	0.805	0.813	3.416	Good
	A35.Toolbox Talk	1.000	0.912	0.835	0.870	3.617	Good
	A36.Effective Control of Subcontractors	1.000	0.672	0.581	0.656	2.909	Average
	A37.Well-maintained Machines and Equipment	1.000	0.863	0.775	0.555	3.193	Average
	A38.Regular Safety Meeting	1.000	0.912	0.824	0.697	3.433	Good
A4. Worker Attitude Level	A41.Safety Awareness	1.000	0.796	0.768	0.760	3.323	Good
	A42.Self-Control	1.000	0.856	0.809	0.775	3.440	Good
	A43.Job Satisfaction	1.000	0.856	0.790	0.688	3.333	Good
	A44.Rule Compliance	1.000	0.818	0.865	0.625	3.308	Good
	A45.Confidence Safety	1.000	0.804	0.769	0.737	3.310	Good
	A46.Safety Reward and Incentive	0.899	0.600	0.604	0.445	2.548	Poor

Remark: ☐ Average level ☐ Good level ☐ Poor level

Table 5 Safety Performance level of medium construction projects

		Availability	Quality of Documents and implementation	Level of implementation in organization	Frequency of updating/ Revision	Total	Performance level
A1. Organization level	A11.Safety Policy	1.000	0.839	0.781	0.442	3.062	Average
	A12.Safety Investment	0.895	0.782	0.627	0.447	2.752	Poor
	A13.Contract and Document	0.987	0.840	0.764	0.368	2.960	Average
	A14.Safety Record	1.000	0.832	0.798	0.653	3.282	Good
	A15.Evaluation	1.000	0.871	0.789	0.632	3.292	Good
	A16.Feedback of post-accident investigation	1.000	0.879	0.732	0.611	3.222	Average
	A17.Duty and responsibility	1.000	0.863	0.776	0.532	3.171	Average
A2. Project level	A21.Safety Management System	1.000	0.824	0.763	0.642	3.229	Average
	A22.Full-time safety officer	1.000	0.763	0.750	0.608	3.121	Average
	A23.Preplanning Risk Assessment	0.842	0.738	0.542	0.511	2.632	Poor
	A24.Induction Training and Education	1.000	0.848	0.640	0.566	3.055	Average
	A25.Safety and health monitoring	1.000	0.847	0.776	0.563	3.187	Average
	A26.Safety Audit	1.000	0.779	0.675	0.411	2.865	Poor
	A27.Emergency Response System	1.000	0.739	0.667	0.445	2.851	Poor
A3. Construction Site level	A31.Information and communication	1.000	0.837	0.785	0.750	3.372	Good
	A32.Safe Work Conditions	1.000	0.884	0.820	0.642	3.346	Good
	A33.Implementation	1.000	0.821	0.781	0.732	3.333	Good

	A34.Work Instruction	1.000	0.750	0.789	0.779	3.318	Good
	A35.Toolbox Talk	1.000	0.816	0.789	0.732	3.337	Good
	A36.Effective Control of Subcontractors	1.000	0.874	0.789	0.766	3.429	Good
	A37.Well-maintained Machines and Equipment	1.000	0.921	0.781	0.632	3.333	Good
	A38.Regular Safety Meeting	0.987	0.840	0.791	0.731	3.349	Good
A4. Worker Attitude Level	A41.Safety Awareness	0.987	0.803	0.791	0.741	3.322	Good
	A42.Self-Control	0.987	0.819	0.796	0.829	3.430	Good
	A43.Job Satisfaction	0.987	0.845	0.800	0.667	3.299	Good
	A44.Rule Compliance	1.000	0.847	0.706	0.711	3.264	Average
	A45.Confidence Safety	0.987	0.819	0.776	0.771	3.352	Good
	A46.Safety Reward and Incentive	0.737	0.650	0.423	0.382	2.192	Poor

Remark: ☐ Average level ☐ Good level ☐ Poor level

Based on the results from Table 4 and Table 5, there were 17 good, 7 average, and 3 poor levels for safety performance for the large construction projects, while there were fewer number of good levels and more poor levels for the medium projects. To be exact, there were 14 good, 9 average, and 5 poor levels. For the medium projects, (A12) Safety Investment and (A26) Safety Audit were at a poor level of performance. This might be because of the limited budget on Safety Investment. Other safety performances of the medium projects that went down from good in general to average level were Safety (A21), Management System, (A22) Full-Time Safety Officer, and (A24) Induction Training and Education. These lowered levels of safety performances might also be affected by the lower budget on safety investment due to the smaller size of the company. On the other hand, the level of performance for Effective Control of Subcontractors and Well-Maintained Machines was at the average level in large projects, which was lowered than that of medium projects, since there were so many subcontractors present on the site. However, both medium and large projects need to put more effort into (A23) Preplanning Risk Assessment, (A26) Emergency Response System, and (A46) Safety Reward and Incentive because these were at the poor level of safety performance.

5. Conclusion

After the authors reviewed the factors that affect safety performance, twenty-eight factors were found and were grouped into four levels of implementation as leading key performance indicators of construction organizations. A questionnaire survey was developed according to the aforementioned indicators .The data were collected from medium and large-size construction projects located in Bangkok and its vicinity. The analyses were carried out with the weighted average formula for each safety performance indicator. At the organization level, the highest performance was A14 (Safety record). At the project level, the highest performance was A22 (Full-Time Safety Officer) while A23 (Pre-Planning Risk Assessment) was the lowest. At the construction site level, A35 (Toolbox talk) had the highest performance. Regarding worker attitude level, the highest performance was by A42 (Self-Control), and A46 (Safety Reward and Incentive) was the lowest .Overall, the organization level, project level, and worker attitude were at an average level of safety performance while the construction site was at a good level.

In comparison, the safety performance levels between medium and large projects were also analyzed. Based on the result, A23 (Preplanning Risk Assessment,)A27 (Emergency System Response), and A46 (Safety Reward and Incentive) were at a poor level of safety performance in both medium and large projects. In a large construction project, a responsible person should improve the control on subcontractors and should plan for the maintenances of machines and equipment. In a medium project, the organization should invest more on safety and conduct safety audit regularly to increase the level of safety performance.

As the author's recommendation, at the organization level, the company must prepare budgets to invest more in safety, such as safety appliances, and put more effort into the feedback of post-accident and conduct investigation regularly. At the project level, a safety audit also needs to be conducted regularly and before the project begins. Pre-planning risk assessment should be considered more seriously as well as the planning for emergency response system. At the construction site level, safety meetings should be regularly conducted .The control of subcontractors to prevent an accident should be indicated in the contract document as well as close monitoring. At the worker attitude level, a reward and incentive should be given to the person who has a good safety performance.

The author developed this simple tool for assessing the safety performance of construction projects as an alternative approach for lagging indicators. As a result of this study, this simplified leading indicator tool could help to point out the weak aspect of safety and could inform decision-makers about them to concentrate on improving the weak aspects, which simplified that leading indicator tool could also help the construction organization to assess their performance and could help in strategic planning of safety to minimize the loss of financial and social resources.

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7. References

Vedder, J., & Carey, E. (2005). A multi-level systems approach for the development of tools, equipment and work processes for the construction industry. *Applied Ergonomics*, *36*(4), 471-480.

Chongsuvivatwong, V., PAS-ONG, S., Ritsmithchai, S., Lebel, L., Kamolrattanakul, P., Dhanamun, B., & Bunteongjit, K. (1998). A multi-centre cross-sectional survey on safety at construction sites in Thailand, 1994-1995. *Journal of Occupational Health*, *40*(4), 319-324.

Poon, S. W., Tang, S. L., & Wong, F. K. (2008). *Management and Economics of Construction Safety in Hong Kong: Dynamics of the Residential Real Estate Market in Hong Kong* (Vol. 1). Hong Kong University Press.

Fernie, S., Leiringer, R., & Thorpe, T. (2006). Change in construction: a critical perspective. *Building Research & Information*, *34*(2), 91-103.

Hinze, J., Thurman, S., & Wehle, A. (2013). Leading indicators of construction safety performance. *Safety Science*, *51*(1), 23-28.

Hallowell, M. R., Hinze, J. W., Baud, K. C., & Wehle, A. (2013). Proactive construction safety control: Measuring, monitoring, and responding to safety leading indicators. *Journal of Construction Engineering and Management*, *139*(10), 04013010.

Rajendran, S., & Gambatese, J. A. (2009). Development and initial validation of sustainable construction safety and health rating system. *Journal of Construction Engineering and Management*, *135*(10), 1067-1075.

Rajendran, S. (2013). Enhancing construction worker safety performance using leading indicators. *Practice Periodical on Structural Design and Construction*, *18*(1), 45-51.

Hsu, I. Y., Su, T. S., Kao, C. S., Shu, Y. L., Lin, P. R., & Tseng, J. M. (2012). Analysis of business safety performance by structural equation models. *Safety Science*, *50*(1), 1-11.

Ng, S. T., Cheng, K. P., & Skitmore, R. M. (2005). A framework for evaluating the safety performance of construction contractors. *Building and Environment*, *40*(10), 1347-1355.

Kulchartchai, O., & Hadikusumo, B. H. (2010). Exploratory study of obstacles in safety culture development in the construction industry: a grounded theory approach. *Journal of Construction in Developing Countries*, *15*(1), 45-66.