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Safety Leading Indicators for Malaysian Construction Industry

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Abstract

More and more safety professionals and researchers agree that lagging indicators are inefficient to provide the necessary insights for preventing accidents. Many encourage a shift to implement leading indicators or proactive initiatives. However, development in leading indicator-based safety performance measurement in Malaysia is still trailing behind. Hence, this study aims to investigate potential safety leading indicators that are applicable for Malaysian construction industry. One hundred and seventy-six (176) questionnaires were administered to subject-matter experts. Results of the survey were analyzed by implementing Mean Score (MS) and Relative Importance Index (RII). Spearman's Rank Correlation Test and Cronbach's Alpha Coefficient were used to ensure the reliability and validity of the questionnaire. All leading indicators are significant and none of them is rejected according to the results. The finding of this study is the first step to develop a leading indicators implementation framework for Malaysian construction industry.

Index Terms—Safety performance, leading indicators, construction industry.

I. INTRODUCTION

Measuring safety performance over a period of time gives an indication on the effectiveness of current accident prevention efforts. Data collected from measuring safety performance can be used to help a company to identify any potential risks at an early stage as well as the required safety measures for any hazards [1].

Lagging factors are the most utilized (e.g., measurement of absence of safety) in evaluating a project's safety performance. However, reactive measurements which define as "after the loss measurements" is only capable of diagnosing the effectiveness of existing safety systems after the occurrence of incidents/accidents. Hence, lagging indicators fail to provide early warnings when the safety program has a weakness [2]. Alternatively, leading indicators are said to be predictive in recent research [3]. In response, more and more literatures support a professional transition from lagging to leading indicators. Through leading indicators, safe practices can be measured while the construction is still on-going to trigger positive responses before an incident/accident happens [4].

Despite there is a growing consensus that transition to the use of leading indicators is needed to resolve the growing rate of accidents and multiple research has been done to explore the implementation of active measurements, development in leading indicator-based safety performance measurement in Malaysia is still trailing behind.

Malaysian construction industry still primarily implements lagging indicators such as number of accidents and fatality rates to evaluate how well a contractor is performing in safety management. It was not until recently that Malaysia's Construction Industry Development Board (CIDB) came out with the only active safety performance measurement tool in Malaysia called Safety and Health Assessment System in Construction (SHASSIC) [5].

However, the tool is considered as incomprehensive. According to literature, safety leading indicators can be categorized into indicators of safety performance measurement of constructors, projects, and individuals as well as indicators that identify potential incidents/accidents due to issues arising from behavior, organization management and project operations [6]. SHASSICS is clearly lacking in the latter. The attributes of safety performance could vary from one project to another depending on the location, scope of work, type of projects and other factors [7]. This has become a huge disadvantage for SHASSIC's indicators as they are not allowed to be tailored. To resolve issues mentioned above, it is essential to investigate safety leading indicators that are applicable for Malaysian construction industry in a wider basis in order to capture all potential leading indicators.

II. OVERVIEW OF SAFETY LEADING INDICATORS

Traditionally, "after-the-loss" type of measurements for instance accident, injury and fatality rates, incidents, and costs, is used to measure construction safety performance [2]. However, accident statistics only indicate the past performance of safety management [8], hence, majority of these methods are reactive approaches. Reactive measurement aims to ensure safety controls in place are sufficient to discover weaknesses or gaps in the control systems by identifying and reporting on incidents [9][10]. It also allows to learn from mistakes. Lagging indicators is able to show when a targeted safety outcome has not been achieved or unsuccessful [11]. The information provided by a lagging indicator is historical in nature. A response will be developed with the aim to hopefully prevent or decrease the rates of accident in the future if the number of incidents is unsatisfactory. The response is not ideal as it is implemented only after accidents have already occurred [1][12]. Further insights on the existing safety conditions cannot be found in the lagging indicators. According to Toellner [10], the mostly used lagging indicators in the U.S. industries are majorly driven by OSHA recordkeeping requirements. However, users interpreted and applied these guidelines differently, which makes these indicators failed to consistently reflect on the safety performance over time.

Leading indicators associates with active measurement and is capable to determine whether a risk control system is operating as intended [13]. Leading indicators are metrics found in measurable systems or individual behaviors linked to accident prevention. They focus on improving performance in safety through measuring, reporting, as well as managing safe behaviors [10]. Leading indicators can also be used to predict safety performance. They act as important inputs to reach the desired safety outcome [11]. Leading indicators are said to be directly related to the projects that are in the process of developing safety management [12]. Moreover, leading indicators can help to determine the probability of delivering a project safely. They provide the opportunity to implement rectification as soon as the weakness is found in safety program [4]. The commonly used leading indicators in the industry are near miss reporting, worker observation (to determine unsafe conditions and acts), job site audits, stop work authority, housekeeping, safety orientation, and training, etc. [4].

The construction industry recently is starting to turn away from safety measures based on lagging indicators for example occurrence rates of accident and compensation costs [6][12]. More and more safety professionals and researchers agree that lagging indicators, are inefficient in providing the necessary insights for preventing accidents because lagging indicators are reactionary and they require accident to occur, or personnel on site must get injured in order to implement the necessary measures [2]. Many newly developed methods encourage a shift to implement upstream/leading indicators or proactive initiatives for instance identification of risks and observed percent safe behavior [14]. Proactive methods put a focus on the current safety related activities with an objective to develop safety performance of a system instead of system failure. For example, risky behaviors and unsafe site conditions can be recorded/measured during the phase of construction which also send indications that preventive measures should be implemented before an injury occurs [4]. Safety leading indicators can be categorized into:

1. Safety performance measurement of constructors, projects, and individuals.
2. Identification of potential incidents/accidents due to issues arising from behavior, organization management and project operations [6].

Table I and Table II showed the categorization of leading indicators identified in the past literature into two dimensions.

III. METHODOLOGY

The research process involved literature review to identify potential safety leading indicators, questionnaire development and distribution, data collection and analysis. A questionnaire survey with Likert scale was selected because of the different views of various respondents. Questionnaire was developed based on the identified safety leading indicators from past studies. A Likert bipolar scale of 1 to 5, where 1 is very low, 2 is low, 3 is medium, 4 is high and 5 is very high, was included to obtain the level of importance of each indicator.

Pilot survey was administered to several construction experts in order to test the correctness of instructions and questions, time and cost to complete the actual survey and etc. However, to test the reliability of the questionnaire, Cronbach's alpha was carried out in Statistical Package for the Social Sciences Software Version 20 (SPSS V20) using the reliability analysis. Also, Spearman's rank was implemented to test the existence of consensus opinion among all groups of respondents. The gathered results were analyzed to obtain the Mean Score and Relative Importance Index (RII) of the indicators.

The outcome of this research heavily depends on the responses of the respondents; hence, the selection of subject matter experts was critical. Selected experts should possess comprehensive knowledge of overall safety aspects and currently or recently participated in construction safety management. The targeted respondents were composed of project directors, project managers, civil engineers, quantity surveyors, architects and safety supervisors. They were selected from developers, academic institutions, consultancy, and contracting firms.

The formula by Israel [24] was used to derive the sample size, n. The formula is stated as below:

$$n = \frac{N}{1 + N(e)^2} \tag{1}$$

where,
N = population and
e = precision 0.05.

The collected results from the questionnaire survey were analyzed to obtain the Mean Score (MS), MS is calculated by:

$$MS = \frac{\sum f \times s}{N} (1 \leq MS \leq 5) \tag{2}$$

where,
f = frequency of responses rating each element,
s = score assigned to each element and
N = number of responses concerning that element.

The MS was then used to calculate the Relative Importance Index (RII) of each indicator by:

$$RII(M_j) = \frac{MS_j}{\sum_{j=1}^{N} MS_j} \tag{3}$$

where,
RII(M)j = relative importance index of the jth element and
MSj = mean score of the jth element.

Table I. Leading Indicators to Measure Safety Performance

Categories	Leading Indicators		Authors
A - Constructor's Safety Management and Strategy		• Written and comprehensive OHS plan • Safety policies conveyed to stakeholders that are relevant • Safety considerations were made systematically in the official plans of constructor and strategy documents • Comprehensible authority, responsibility, and accountability in project health and safety	[4][15][16][17]
B - Upper Management Commitment in Safety and Supervision		• Management has active participation in safety activities • Frequency of safety walks done by management • Frequency of mentioning safety in the management meetings	[10][17]
C - Safety Education and Trainings		• Conduct emergency training on-site regularly • Supervisor safety related training hours • Safety and health induction and training for new workers • Frequency of completed safety training sessions vs. planned (in %) • Number of safety trained personnel on site • Number of safety trained site supervisors	[4][15][18][19][20]
D - Safety in Contract Documents and Responsibilities of Stakeholders	D1 - Contract and Design	• Including minimum ratio of safety supervisors to labours in contract • Consider safety in design phase • Including work hour restrictions for labours in contract	[12][17][18][19][20]
	D2 - Contractor	• Past safety performance as a criterion in contractor selection • Conduct trainings for contractors on safe practices and safety culture • Mandatory attendance from all contractors in safety meetings	
	D3 - Subcontractors/Vendors	• Mandatory attendance from all subcontractors in safety meetings • Subcontractor/vendor management • Selecting subcontractors on the basis of satisfying safety criteria (in %)	

	D4 - Client	• OHS plan reviewed and approved by client • Frequency of safety walkthroughs by client • Frequency of client's participation in worker safety induction • Promotion of site safety by client	
E - Workplace Investigations	E1 - Safety Audits	• Auditing program is in place • Score of safety audit is calculated and monitored • Safety audits completed vs. planned (in %) • Safety compliance on work site safety audits (in %)	[2][12][17][19][20][21]
	E2 - Investigation of Accidents	• Accident/incident is investigated with approved procedure • Percentage of incident/accident reports on which root cause analysis was conducted • Workers' satisfaction on the investigations and measures taken after the occurrence of accidents, injuries and near misses	
	E3 - Near Miss Investigation	• System to analyse near miss events is in place • Frequency of near misses reported per 200,000 worker-hours	
	E4 - Identification of Hazards and Corrective Measures	• Corrective action program is developed to rectify deviations in construction • Adequate barriers for hazards/risks are in place	
F - Safety Plant and Equipment Implementation		• PPE on site is adequately provided and maintained	[22]
G - Housekeeping on Site		• Construction site has adequate scrap, waste disposal system in place • Construction site has adequate designated area for scrap, waste disposal	[12][18]
H - Workers' Health and Welfare		• Substance abuse program for workers is promoted and conducted	[17]

I - Safety Meetings	• Site toolbox safety meetings are held • Frequency of toolbox meetings conducted • Attendance of site supervisors/ managers in toolbox meetings • Pre-task planning meetings are held • Frequency of pre-task planning meetings • Attendance of site supervisors/ managers in pre-task planning meetings	[2][19][20] [23]

Table II. *Leading Indicators to Measure Safety Performance*

Categories	**Leading Indicators**		**Authors**
A - Constructor's Safety Management and Strategy	• On -site plans were constructed according to in-depth site hazards/risks identification		[4][15][16][17]
B - Upper Management Commitment in Safety and Supervision	• Superiors' feedback on workers' safety-conscious behaviour • Ensuring that every action is in compliance with the existing policies. • Safety walks done by management to identify risks and hazards on site		[10][17]
C- Safety in Contract Documents and Responsibilities of Stakeholders	• Subcontractors/Vendors exit interview to identify potential risks and hazards on site.		[12][17][18][19] [20]
D - Workplace Investigations	D1 - Observation of Workers' Behaviour	• Workers' unsafe behaviours records. • Frequency of not complying to safe work procedures by workers.	[2][12][17][19][20][21]
	D2 - Identification of Hazards and Corrective Measures	• Identifying risks associated with routine and nonroutine operations. • Measuring and monitoring hazardous agents at work. • Construct project policies, work procedures and practices according to hazards identification and risk assessments	
E - Safety Plant and Equipment Implementation	• PPE on site is adequately provided and maintained • Plant and equipment inspection		[22]
F - Authority of Workers on Site	• Frequency of Stop Work Authority • Hazards, Incidents and Accidents Reporting		[15][18]

G - Housekeeping on Site	• Inspection on the cleanliness and tidiness of construction site	[12][18]
H - Workers' Health and Welfare	• Performing periodic medical examination at regular intervals. • Negative results on random drug tests (in %) • Number of labours reporting stress at work.	[12][18]

IV. RESULTS AND DISCUSSION

A. *Demographic Information of the Respondents*

In relation to the one hundred and seventy-nine (176) questionnaires that were administered, one hundred and sixty-four (164) were correctly answered and found useful for this research. The usable questionnaires represent 95.34% of the administered questionnaires.

Among 164 respondents, 52 of them have less than 3 years (31.7%) of experience, 8 respondents have 4 to 6 years (4.87%) of experience, 12 have 7 to 9 years (7.32%) of experience and 92 respondents have more than 10 years (56.1%) of experience. However, with the level of the percentage of 57% (7.32+56.1=63.42) of the respondents having an experience above 7 years, their responses are adequately enough to rely upon and found very useful for the analysis. 4 respondents (2.4%) have academic qualification of SPM or equivalent, 92 respondents (56.1%) have a bachelor's degree, 48 respondents with (29.3%) a MSc, and 20 of them (12.2%) are professional engineers, with an indication that 98% of the respondents are holders of degrees. Respondents mostly comprised of engineers (104 or 63.4%), follows by project managers (16 or 9.7%), supervisors (14 or 8.5%), project directors (12 or 7.3%), academicians (12 or 7.3%), general workers had the least involvement, accounted at 3.7% or 6 respondents.

B. *Result Analysis - Leading Indicators to Measure Safety Performance*

Table III shows the MS and RII of Category A safety leading indicators. Among 4 leading indicators, safety considerations were made systematically in the official plans of constructor and strategy documents (MS= 4.34) as well as comprehensible authority, responsibility, and accountability in project health and safety (MS= 4.25) were the most crucial, follow by written and comprehensive OHS plan (MS= 4.12). Safety policies conveyed to stakeholders that are relevant (MS= 3.96) had the lowest MS thus made them the least important indicators in Category A. According to RII results, all indicators fell under high or high-medium importance levels.

Table. III *Category A Mean Score and Relative Importance Index*

Safety Leading Indicators	MS	RII
Written and comprehensive OHS plan	4.12	0.790
Safety policies conveyed to stakeholders that are relevant	3.96	0.658
Safety considerations were made systematically in the official plans of constructor and strategy documents	4.34	0.823
Comprehensible authority, responsibility, and accountability in project health and safety	4.25	0.798

Table IV shows the MS and RII of Category B safety leading indicators. Frequency of safety walks done by management (MS= 4.22) is the most crucial. Management has active participation in safety activities (MS= 4.02) ranks. According to RII results, all indicators fell under high or high-medium importance levels.

Table IV. *Category B Mean Score and Relative Importance Index*

Safety Leading Indicators	MS	RII
Management has active participation in safety activities	4.02	0.776
Frequency of safety walks done by management	4.22	0.813

Table V shows the MS and RII of Category C safety leading indicators. Number of safety trained personnel on site (MS= 4.57) and conduct emergency training on-site regularly (MS= 4.48) are the most crucial. Frequency of completed safety training sessions vs. planned (in %) (MS= 4.36), number of safety trained site supervisors (MS= 4.35) and safety and health induction and training for new workers (MS= 4.26) ranks third, fourth and fifth. Supervisor safety related training hours (MS= 4.08) ranks last. According to RII results, all indicators fell under high or high-medium importance levels.

Table V. *Category C Mean Score and Relative Importance Index*

Safety Leading Indicators	MS	RII
Conduct emergency training on-site regularly	4.48	0/864
Supervisor safety related training hours	4.08	0.735
Safety and health induction and training for new workers	4.26	0.796
Frequency of completed safety training sessions vs. planned (in %)	4.36	0.842
Number of safety trained personnel on site	4.57	0.875
Number of safety trained site supervisors	4.35	0.837

Table VI shows the MS and RII of Category D safety leading indicators. Past safety performance as a criterion in contractor selection (P) (in %) (MS= 4.45) is the most crucial follow by consider safety in design phase (MS= 4.35), mandatory attendance from all subcontractors in safety meetings (MS= 4.35), OHS plan reviewed and approved by client (MS= 4.34), management has active participation in safety activities Including work hour restrictions for labours in contract (MS= 4.29), mandatory attendance from all contractors in safety meetings (MS= 4.27), selecting subcontractors on the basis of satisfying safety criteria (in %) (MS= 4.09), promotion of site safety by client (MS= 4.04), and including minimum ratio of safety supervisors to labours in contract (MS= 3.68), and frequency of client’s participation in worker safety induction (MS= 3.64) ranks last. According to RII results, all indicators fell under high or high-medium importance levels.

Table VI. *Category D Mean Score and Relative Importance Index*

Safety Leading Indicators	MS	RII
Including minimum ratio of safety supervisors to labours in contract	3.68	0.624
Consider safety in design phase	4.35	0.834
Including work hour restrictions for labours in contract	4.29	0/826
Past safety performance as a criterion in contractor selection	4.45	0.865
Mandatory attendance from all contractors in safety meetings	4.27	0.824
Mandatory attendance from all subcontractors in safety meetings	4.35	0.859
Selecting subcontractors on the basis of satisfying safety criteria (in %)	4.09	0.782
OHS plan reviewed and approved by client	4.34	0.846
Frequency of client’s participation in worker safety induction.	3.64	0.613
Promotion of site safety by client	4.04	0.776

Table VII shows the MS and RII of Category E safety leading indicators. Adequate barriers for hazards/risks are in place (MS= 4.86) is the most crucial, follow by safety compliance on work site safety audits (in %) (MS= 4.59), corrective action program is developed to rectify deviations in construction (MS= 4.47), Auditing program is in place (MS= 4.36), frequency of near misses reported per 200,000 worker-hours (MS= 4.35), Safety audits completed vs. planned (in %) (MS= 4.23), system to analyse near miss events is in place (MS= 4.23), accident/incident is investigated with approved procedure (MS= 4.13), percentage of incident/accident reports on which root cause analysis was conducted (MS= 3.98) and workers' satisfaction on the investigations and measures taken after the occurrence of accidents, injuries and near misses (MS= 3.67) which ranks last. According to RII results, all indicators fell under high or high-medium importance levels.

Table VII. *Category E Mean Score and Relative Importance Index*

Safety Leading Indicators	**MS**	**RII**
Auditing program is in place	4.36	0.842
Safety audits completed vs. planned (in %)	4.23	0.829
Safety compliance on work site safety audits (in %)	4.59	0.887
Accident/incident is investigated with approved procedure	4.13	0.786
Percentage of incident/accident reports on which root cause analysis was conducted	3.98	0.673
Workers' satisfaction on the investigations and measures taken after the occurrence of accidents, injuries and near misses	3.67	0.621
System to analyse near miss events is in place	4.23	0.794
Frequency of near misses reported per 200,000 worker-hours	4.35	0.825
Corrective action program is developed to rectify deviations in construction	4.47	0.866
Adequate barriers for hazards/risks are in place.	4.86	0.947

Table VIII shows the MS and RII of Category F safety leading indicators. PPE on site is adequately provided and maintained (MS= 4.68) is considered as crucial indicators. According to RII results, the indicators fell under high importance level.

Table VIII. *Category F Mean Score and Relative Importance Index*

Safety Leading Indicators	**MS**	**RII**
PPE on site is adequately provided and maintained	4.68	0.884

Table IX shows the MS and RII of Category G safety leading indicators. Construction site has adequate housekeeping program (MS= 3.86) is considered as crucial indicators. According to RII results, the indicators fell under medium high importance level.

Table IX. *Category G Mean Score and Relative Importance Index*

Safety Leading Indicators	**MS**	**RII**
Construction site has adequate housekeeping program	3.86	0.684

Table X shows the MS and RII of Category H safety leading indicators. Substance abuse program for workers is promoted and conducted (MS= 4.08) is considered as crucial indicators. According to RII results, the indicators fell under high importance level.

Table X. *Category H Mean Score and Relative Importance Index*

Safety Leading Indicators	MS	RII
Substance abuse program for workers is promoted and conducted	4.08	0.749

Table XI shows the MS and RII of Category I safety leading indicators. Among 6 leading indicators, frequency of toolbox meetings conducted (MS= 4.67) and attendance of site supervisors/ managers in toolbox meetings (MS= 4.59) are the most crucial. Pre-task planning meetings are held (MS= 4.54), Site toolbox safety meetings are held (MS= 4.46) and frequency of pre-task planning meetings (MS= 4.25) ranks third, fourth and fifth. Attendance of site supervisors/ managers in pre-task planning meetings (MS= 4.21) ranks last. According to RII results, all indicators fell under high importance level.

Table XI. *Category I Mean Score and Relative Importance Index*

Safety Leading Indicators	MS	RII
Site toolbox safety meetings are held	4.46	0.875
Frequency of toolbox meetings conducted	4.67	0.915
Attendance of site supervisors/ managers in toolbox meetings	4.59	0.902
Pre-task planning meetings are held	4.54	0.893
Frequency of pre-task planning meetings	4.25	0.879
Attendance of site supervisors/ managers in pre-task planning meetings	4.21	0.844

C. Result Analysis - Leading Indicators to Identify Potential Incidents/Accidents

The questions relate to leading indicators to measure safety performance are divided into 8 categories, which comprise 18 leading indicators. Table XII shows the MS and RII of Category A safety leading indicators. On -site plans were constructed according to in-depth site hazards/risks identification (MS= 4.35) is considered as crucial indicators. According to RII results, the indicators fell under high importance level.

Table XII. *Category A Mean Score and Relative Importance Index*

Safety Leading Indicators	MS	RII
On -site plans were constructed according to in-depth site hazards/risks identification	4.35	0.862

Table XIII shows the MS and RII of Category B safety leading indicators. Among 3 leading indicators, superiors' feedback on workers' safety-conscious behavior (MS= 4.63) is the most crucial. Safety walks done by management to identify risks and hazards on site (MS= 4.39) ranks second. Ensuring that every action is in compliance with the existing policies (MS= 4.34) ranks last. According to RII results, all indicators fell under high importance level.

Table XIII. *Category B Mean Score and Relative Importance Index*

Safety Leading Indicators	MS	RII
Superiors' feedback on workers' safety-conscious behaviour	4.63	0.928
Ensuring that every action is in compliance with the existing policies	4.34	0.870
Safety walks done by management to identify risks and hazards on site	4.39	0.888

Table XIV shows the MS and RII of Category C safety leading indicators. Subcontractors/Vendors exit interview to identify potential risks and hazards on site (MS= 4.24) is considered as crucial indicators.

According to RII results, the indicators fell under high importance level.

Table XIV. *Category C Mean Score and Relative Importance Index*

Safety Leading Indicators	MS	RII
Subcontractors/Vendors exit interview to identify potential risks and hazards on site	4.24	0.821

Table XV shows the MS and RII of Category D safety leading indicators. Among 5 leading indicators, frequency of not complying to safe work procedures by workers (MS= 4.67) is the most crucial. Workers' unsafe behaviors records (MS= 4.48) ranks second, follow by identifying risks associated with routine and nonroutine operations (MS= 4.37), measuring and monitoring hazardous agents at work (MS= 4.26) and construct project policies, work procedures and practices according to hazards identification and risk assessments (MS= 4.20) which ranks last. According to RII results, all indicators fell under high importance level.

Table XV. *Category D Mean Score and Relative Importance Index*

Safety Leading Indicators	MS	RII
Workers' unsafe behaviors records	4.48	0.904
Frequency of not complying to safe work procedures by workers	4.67	0.945
Identifying risks associated with routine and nonroutine operations	4.37	0.852
Measuring and monitoring hazardous agents at work	4.26	0.844
Construct project policies, work procedures and practices according to hazards identification and risk assessments	4.20	0.829

Table XVI shows the MS and RII of Category E safety leading indicators. Among 2 leading indicators, PPE on site is adequately provided and maintained (MS= 4.76) is the most crucial. Frequency plant and equipment inspection (MS= 4.63) ranks second. According to RII results, all indicators fell under high importance level.

Table XVI. *Category E Mean Score and Relative Importance Index*

Safety Leading Indicators	MS	RII
PPE on site is adequately provided and maintained	4.76	0.967
Frequency plant and equipment inspection	4.63	0.945

Table XVII shows the MS and RII of Category F safety leading indicators. Among 2 leading indicators, hazards, Incidents and Accidents Reporting (MS= 4.53) is the most crucial. Frequency of Stop Work Authority (MS= 4.34) ranks second. According to RII results, all indicators fell under high importance level.

Table XVII. *Category F Mean Score and Relative Importance Index*

Safety Leading Indicators	MS	RII
Frequency of Stop Work Authority	4.34	0.893
Hazards, Incidents and Accidents Reporting	4.53	0.928

Table XVIII shows the MS and RII of Category G safety leading indicators. Inspection on the cleanliness and tidiness of construction site (MS= 4.47) is considered as crucial indicators. According to RII results, the indicators fell under high importance level.

Table XVIII. *Category G Mean Score and Relative Importance Index*

Safety Leading Indicators	MS	RII
Inspection on the cleanliness and tidiness of construction site	4.47	0.920

Table XIX shows the MS and RII of Category H safety leading indicators. Among 3 leading indicators, negative results on random drug tests (in %) (MS= 4.38) is the most crucial. Performing periodic medical examination at regular intervals (MS= 4.21) ranks second. Number of labours reporting stress at work (MS= 3.97) ranks last. According to RII results, all indicators fell under high and high-medium importance levels.

***Table XIX**. Category H Mean Score and Relative Importance Index*

Safety Leading Indicators	MS	RII
Performing periodic medical examination at regular intervals	4.21	0.873
Negative results on random drug tests (in %)	4.38	0.897
Number of labours reporting stress at work	3.97	0.767

D. Reliability and Validity Test

The reliability of the survey data is reported in Table XX Cronbach's alpha coefficient of main element and sub-elements are 0.990 and 0.992 respectively. These results which were close to 1 showed that the questionnaires' data are reliable. Also, validity of the survey which is equal to the square root of the reliability coefficient is tabulated in Table 4. First and second part of the survey scored a validity of 0.995 and 0.996 which are close to 1. Hence, the questionnaire's validity is high and is able to measure what it was constructed to measure.

***Table XX.** Cronbach's Alpha Coefficient*

Element of Framework	Cronbach's alpha coefficient
Leading Indicators to Measure Safety Performance	0.990
Leading Indicators to Identify Potential Incidents/Accidents	0.992

Table XXI and XXII show the results of Spearman's rank correlation test. The test shows the relationship between the opinions of the clients, the consultants, the contractors and those who work in academic sector on the level of importance of different FFH safety measures.

For Table XXI, the correlation coefficients between two parties from highest to lowest are academic and contractor (0.952), contractor and client (0.944), academic and consultant (0.928), client and consultant (0.924) and last but not least contractor and consultant (0.908). All coefficients indicated high correlations among all groups of respondents. P-values (Sig.) which are 0.000, 0.000, 0.000 and 0.000 respectively proved that the perceptions of the four parties did not differ.

For Table XXII, the correlation coefficients between two parties from highest to lowest are consultant and contractor (0.964), contractor and academic (0.947), academic and client with 0.939, client and consultant (0.935) and last but not least contractor and client (0.912). All coefficients indicated high correlations among all groups of respondents. P-values (Sig.) which are 0.000, 0.000, 0.000 and 0.000 respectively proved that the perceptions of the four parties did not differ.

V. CONCLUSION

This research investigates the potential safety leading indicators that are applicable for contractors in Malaysia in two dimensions, indicators of safety performance measurement of constructors, projects, and individuals as well as indicators that identify potential incidents/accidents due to issues arising from behavior, organization management and project operations. The results from Mean Score (MS) and Relative Important Index (RII) showed that all potential indicators are significant and capable of predicting safety performance of construction projects and potential incidents/accidents on site. The most significant safety performance predictors are adequate barriers for hazards/risks are in place, PPE on site is adequately provided and maintained and frequency of toolbox meetings conducted, while the most significant potential incidents/accidents predictors are PPE on site is adequately provided and maintained, frequency of not complying to safe work procedures by workers and superiors' feedback on workers' safety-conscious behavior. The finding of this study is the first step of developing a framework for leading indicators in Malaysian construction industry.

Table XXI. *Correlation of Opinions on Leading Indicators to Measure Safety Performance*

			Client	**Consultant**	**Contractor**	**Academic**
Spearman's rho	Client	Correlation Coefficient	1.000	.924(**)	.944(**)	.912(**)
		Sig. (1-tailed)	.-	.000	.000	.000
		N	5	5	5	5
	Consultant	Correlation Coefficient	.924(**)	1.000	.908(**)	.928(**)
		Sig. (1-tailed)	.000	-.	.000	.000
		N	5	5	5	5
	Contractor	Correlation Coefficient	.944(**)	.908(**)	1.000	.952(**)
		Sig. (1-tailed)	.000	.000	-.	.000
		N	5	5	5	5
	Academic	Correlation Coefficient	.912(**)	.928(**)	.952(**)	1.000
		Sig. (1-tailed)	.000	.000	.000	.-
		N	5	5	5	5

Table XXII. *Correlation of Opinions on Leading Indicators to Identify Potential Incidents/Accidents*

			Client	**Consultant**	**Contractor**	**Academic**
Spearman's rho	Client	Correlation Coefficient	1.000	.935(**)	.912(**)	.939(**)
		Sig. (1-tailed)	.-	.000	.000	.000
		N	20	20	20	20
	Consultant	Correlation Coefficient	.935(**)	1.000	.964(**)	.914(**)
		Sig. (1-tailed)	.000	-.	.000	.000
		N	20	20	20	20
	Contractor	Correlation Coefficient	.912(**)	.964(**)	1.000	.947(**)
		Sig. (1-tailed)	.000	.000	-.	.000
		N	20	20	20	20
	Academic	Correlation Coefficient	.939(**)	.914(**)	.947(**)	1.000
		Sig. (1-tailed)	.000	.000	.000	.-
		N	20	20	20	20

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