Factors Influencing Construction Safety Equipment Selection

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***Abstract*—Construction industry is a hazardous industry that comprises a wide range of activities, involving construction, alteration, and/or repair of all types of building and structures. Activities that construction workers engage in may expose them to a wide variety of health hazards. In Thailand, the construction industry is ranked the first on occupational injuries and illnesses that come from, for example, inappropriate use of personal protective equipment, removing safety guards from the workplace, and ineffectiveness of safety signs and symbols used in construction sites. This paper, therefore, focuses on examining key factors influencing the construction safety equipment selection utilizing the exploratory factor analysis method. A total of 20 items affecting the selection decision are extracted from the construction-related literatures, and are used for questionnaire survey development. The analysis results group the 20 items into six key factors, namely 1) the Safety-related Policy, 2) the Equipment Design, 3) the Personal, 4) the Cost Value, 5) the Supplier Agreement, and 6) the Supplier Support factors. The results also suggest that the suppliers' relationship, the after sale service, the site condition, the workers' attitude, the compatibility function, and the comfortability issues must be considered when making the selection decision.**

***Index Terms*—construction industry, exploratory factor analysis, safety equipment selection**

I. Introduction

Construction involves many hazardous activities that may expose workers to a wide variety of health hazards. In Thailand, the construction industry is ranked the first in terms of occupational injuries and illnesses. According to Aksorn and Hadikusumo [1], major causes of accidents may come from, for example, inappropriate use of Personal Protective Equipment (PPE), removing safety guards from the workplace, and inadequate provision of safety signs on the construction sites. Safety program implementation is often neglected on construction sites and rarely managed correctly. Full support from management is found crucial success of safety program implementation, including issuing a comprehensive safety policy, allocating sufficient safety resources, promptly reacting to safety suggestions and complaints, and selecting proper safety equipment to ensure workers' safety [1].

This paper, therefore, focuses on investigating key factors affecting construction safety equipment selection. It is expected that the study results assist construction organizations in making decisions on safety equipment selection.

II. Items Associated with Construction Safety Equipment Selection

Many construction- and safety-related researches have been done to identify possible items influencing safety equipment selection decision. A total of 20 items are listed below. They are used to develop a questionnaire survey to collect data for the analyses.

1) *Workers' Attitude (ATT):* Tam and Fung [2] stated that many construction workers felt uncomfortable in wearing PPE, as it reduced their job performance. Management, therefore, has to establish safe work condition to ensure that safety devices are in good condition, and allocate sufficient budget to support necessary safety activities.
2) *Feedback (FBK):* Safety feedback from workers is useful when considering safety equipment selection. As it reflects problems under real conditions of use [2].
3) *Accident Record (REC):* According to Gibb et al. [3], accident record was used in accident causality analysis.
4) *Comfortability (CFT):* Oversized clothing was found to be uncomfortable and also became a safety issue [4].
5) *Workers' Physical Condition (PHY):* It is important to concern of workers' specific requirements when selecting safety equipment [4].
6) *Language Barrier (LNG):* When workers were required to be trained for safety equipment use, their cultural and linguistic background became a problem because they could not understand the manual given [5].
7) *Equipment Quality (EQL):* Poor quality safety equipment is one of the key issues in equipment selection. Many accidents were contributed to by poor quality safety equipment being used [6].
8) *Cost (CST):* Cameron et al. [7] stated that cost was often recognized as one of factors in equipment selection.

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9) *National Law and Regulation (NLR):* In Thailand, it is compulsory that any safety equipment provided must, at least, meet with the Thailand's Industrial Product Standard [8].
10) *Compatibility Function (CPT):* A crucial element of maintaining safety, beyond proper usage, was that each item of safety equipment interfaces well with other items [4].
11) *Equipment Warranty (WRT):* Best safety equipment selection should be preceded by selection of reliable suppliers, in which warranties offered is one of the listed requirements to gauge supplier efficiency [9], [10].
12) *Ease of Use (EOU):* One of the factors that supported safety equipment compliance was the ease of use [4].
13) *Equipment Design (DES):* Poor equipment design could lead to accidents in the workplace [6].
14) *Site Condition (SCD):* Different safety equipment is required with different site condition [8].
15) *Aftersales Service (ASS):* Suppliers that offer better service, such as easy accessibility, fast response, and flexibility were more preferable to customers [9], [10].
16) *Supplier Delivery Time (SDT):* It is always preferred by the buying organizations that products be delivered as promised [9], [10].
17) *Supplier Relationship (SRL):* It is beneficial, in terms of competitive advantages, for both supplier and the buying organization to keep long-term relationship [9], [10].
18) *Term of Payment (TOP):* One of the criteria that accounts for a significant score when it comes to making decision is the terms of payment that suppliers offered to the organization [9], [10].
19) *Availability of Safety Equipment (ASE):* Since safety equipment is a key issue in construction site, the replacement for the used ones should available. [9], [10].
20) *Supplier Stability (STB):* To ensure reliability of the selected supplier, an important factor that needs to be investigated is the stability of the supplier [9], [10].

III. Questionnaire Survey and Preliminary Analyses

A questionnaire survey is developed to collect data from the medium- and large-sized construction companies, with at least 50 employees, in Bangkok, Thailand. Target respondents were from management and operational levels to gain mix perception regarding the safety equipment selection.

A total of 800 questionnaire surveys were distributed, with 203 returns, representing 25% response rate. From the returned responses, 36 were removed due to data incompleteness. As a result, 167 questionnaires were used for further analysis. It was found that around 40% of the respondents were in management level. The majority of the respondents has been working in the construction industry for at least 5 years, and have been involved in safety equipment selection. Moreover, more than half of the respondents have once attended safety training course.

The collected data were screened, using a number of statistical methods, to increase confidentiality in data, including normality and outlier tests. The skewness and kurtosis values are used to test normality of the data. Skewness relates to the symmetry of the distribution; a skewed variable is a variable whose mean is not in the centre of the distribution.

Kurtosis, on the other hand, relates to the peakedness of a distribution; a distribution is either too peaked (with short, thick tails), or too flat (with long, thin tails). When a distribution is normal, the values of skewness and kurtosis are zero [11]. If there is a positive skewness, there is a pileup of cases to the left, and the right tail is too long; with negative skewness, the result is reversed. Kurtosis values above zero indicate a distribution that is too peaked, while kurtosis values below zero are reversed. Non-normal kurtosis produces an underestimate of the variance of a variable.

The values of skewness and kurtosis less than 2 and 7, respectively, are recommended [12]. The results, as shown in Table I, proved that all 20 items showed normal distribution, with the skewness and kurtosis values in the acceptable ranges.

TABLE I. Skewness and Kurtosis Values

Item	Skewness	Kurtosis
ATT	-0.77	0.32
FBK	-0.59	0.46
REC	-0.53	-0.37
CFT	-0.55	0.42
PHY	-0.45	-0.04
LNG	-0.50	-0.09
EQL	-0.90	0.38
CST	-0.97	1.42
NLR	-0.30	-0.16
CPT	-0.80	1.13
WRT	-0.86	1.53
EOU	-0.49	-0.04
DES	-0.65	-0.37
SCD	-0.43	-0.84
ASS	-0.69	0.12
SDT	-0.39	-0.26
SRL	-0.38	-0.22
TOP	-0.40	-0.03
ASE	-0.36	-0.40
STB	-0.83	0.42

The 5% trimmed mean and the box-plot methods were used to identify the potential outliers. The 5% trimmed mean is a mean calculated from the cases in which 5% of the top and the bottom of the cases are removed [11]. The big difference between a mean and its 5% trimmed mean

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indicates a potential outlier. Box plot, similarly, indicates data with potential outliers.

As a result, four data sets were identified as outliers (see Table II), and were then removed from the data file, resulting in the remaining of 163 items for the exploratory factor analysis.

TABLE II. POTENTIAL OUTLIERS

Data Number	Item	Frequency of Potential Outlier
117	CFT, LNG, SRL, TOP	4
128	CST, CPT, SRL, STB	3
129	CST, CPT, SRL, STB, TOP	4
147	REC, CFT, EQL, CST, DES, ASE, GRT, SCD	8

IV. EXPLORATORY FACTOR ANALYSIS

The screened data were then analysed, using the exploratory factor analysis (EFA), to determine relationship among variables and recreate a pattern of factors [11]. In this study, the principal component, together with varimax rotation, the eigenvalue over 1, and factor loading 0.4 were used for analysis [12]. Kaiser-Meyer-Olkin (KMO) and Bartlett's test of Sphericity were also used to screen whether the data was appropriate for factor analysis. The cut off value of KMO is 0.5, while the Bartlett's test of Sphericity should have $p < 0.5$ [11]. The first run of the EFA, extracts the 20 items into six key factors, accounted for 65.2% of total variance (see Table III). The first factor consists of four items mainly explain the agreement between the buyer and seller; thus, it is named the Supplier Agreement factor [9], [10].

The second factor consists of four items explaining services and supports from the supplier; thus, it is named the Supplier Support factor. The third factor, with four associated items indicates the influence employees have towards the selection of safety equipment. This factor is therefore named the Personal factor. The fourth factor grouped four items; most of which describe the design and use of safety equipment, therefore, it is called the Equipment Design factor. The fifth factor is associated with two items, and is named the Safety-related Policy factor.

TABLE III. EXPLORATORY FACTOR ANALYSIS RESULTS

Item	Factor extracted					
	Supplier Agreement	Supplier Support	Personal	Equipment Design	Safety-related Policy	Cost Value
Supplier Relationship (SDT)	0.84					
Term of Payment (TOP)	0.81					
Supplier Stability (STB)	0.80					
Supplier Delivery Time (SDT)	0.56					
After Sale Service (ASS)		0.82				
Equipment Warranty (WRT)		0.72				
Availability of Safety Equipment (ASE)		0.65				
Equipment Quality (EQL)		0.48				
Attitude (ATT)			0.76			
Feedback (FBK)			0.66			
Language Barrier (LNG)			0.60			
Physical Condition (PHY)			0.47			
Comfortability (CFT)				0.67		
Equipment Design (DES)				0.67		
Ease of Use (EOU)				0.65		
Accident Record (REC)				0.57		
Site Condition (SCD)					0.78	
National Law and Regulation (NRL)					0.74	
Compatibility (CPT)						0.75
Cost (CST)						0.61

The reliability analysis is then performed to confirm the internal consistency of the six factors extracted. The Cronbach's alpha of greater than 0.4 was considered reliable [11]. The results show that all six factors have alpha values ranging from 0.42 to 0.84, thus are considered reliable (see Table IV).

TABLE IV. INTERNAL CONSISTENCY VALUE

Factor and Item	Cronbach Alpha	Cronbach Alpha if Item Deleted
Supplier Agreement Factor	0.84	-
Supplier Delivery Time (SDT)		0.84
Supplier Relationship (SRL)		0.75
Supplier Stability (STB)		0.77
Term of Payment (TOP)		0.79
Supplier Support Factor	0.74	-
Equipment Quality (EQL)		0.74
Availability of Safety Equipment (ASE)		0.72
After sales service (ASS)		0.61
Equipment Warranty (WRT)		0.64
Personal Factor	0.75	-
Attitude (ATT)		0.71
Feedback (FBK)		0.70
Language Barrier (LNG)		0.65
Physical Condition (PHY)		0.69
Equipment Design Factor	0.65	-
Accident Record (REC)		0.57
Comfortability (CFT)		0.63
Equipment Design (DES)		0.54
Ease of Use (EOU)		0.58
Cost Value Factor	0.42	-
Cost (CST)		N/A
Compatibility (CPT)		N/A
Safety-related Policy Factor	0.73	-
National Law and Regulation (NLR)		N/A
Site Condition (SCD)		N/A

V. CONCLUSION AND FURTHER STUDY

Construction work involves many hazardous activities that may expose workers to a wide variety of health hazards. Full support from management can result in successful safety implementation, which will result in reduction of injuries at work. This paper examines key factors influencing construction safety equipment selection. A total of 20 items associated with construction safety are extracted from the literatures, and are analyzed with the exploratory factor analysis. The results show six key factors, including 1) the Safety-related Policy, 2) the Equipment Design, 3) the Personal, 4) the Cost Value, 5) the Supplier Agreement, and 6) the Supplier Support factors. It is also found that the relationship with the suppliers, the workers' attitude towards safety, and the compatibility and comfortability of safety equipment are among critical issues the construction companies should concern in the selection process.

The six key factors influencing construction safety equipment selection will further be used to develop the interview questions for the analytic hierarchy process to examine the importance weight of each key factor in making the construction safety equipment decision.

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