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Identifying Root Causes of Construction Accidents: Non – Human Error Factors

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***Abstract*—** This paper examines root causes of construction accident in a non-human error aspect. A questionnaire survey method was implemented with 21 attributes to gather data from a total of 20 construction companies in Thailand. a total of 255 questionnaire surveys were sent and 163 responses were received. To analyze the dataset, a series of preliminary analyses and exploratory factor analysis were performed. The analyses results reveal three key factors influencing construction accidents, which are ergonomic design, supporting policy, and environment. The directional relationships of these three groups were determined with the structural equation modeling (SEM) method. It is found that to establish appropriate safety policy, the environmental and ergonomic issues, such as ventilation, light, equipment design, and site layout, should be considered.

***Index Terms*—** Construction Accidents; Non – Human Error

I. Introduction

Accident is the main issue to consider in any industries, construction industry is no exception. It is a high-risk industry that covers a wide range of activities involving construction, modification, and/or reparations [1]. In Thailand the rate of accident and fatalities in construction industry is the highest. There are at least 60,000 fatal accidents in a construction site annually around the world and the fatality rate for construction industry is almost higher than the national average among industries worldwide [2].

Most of the accidents are caused by human error. The human error is considered as an undesirable human decision or action that reduces the effectiveness of safety or system performance. Examples are misuse of equipment and tools and misconduct of workers [3]. However, there are other factors that cause accident [4] for example, mentioned that inappropriate ergonomic design, such as inadequate light, exceeding noise and vibration of equipment could cause accident. Moreover, quality of material, equipment technology and personal protective equipment (PPE) could also be the cause of hazard [5]. This research study, therefore, focuses on identifying the root causes of accidents from a non-human errors perspective.

II. Items Influencing Construction Accidents: Non – Human Error

A. Light (LHT)

Light linked to visibility related accident in workplace. In some occasion, insufficient lighting and blind spots can cause accidents [6][9]. Sometimes glare reflected from equipment and tool can disrupt visibility in a person field of vision causing run over accidents [3][7][8].

B. Weather (WTH)

Working environment and variety of natural phenomenon can cause fatalities on site, as most of these are unpredictable. This includes rain, wind, earthquake, flooding and landslides [3][10][11][12].

C. Sunlight (SUN)

Working under direct sunlight for a long period of time may cause heat rashes, heat exhaustion, and heat stroke. This could lead to a more serious health-related issues, and accident [13][14][15][18].

D. Ventilation (VEN)

Working in an enclosed space with no ventilation making it hard to breathe [7][8][13].

E. Dust (DUS)

Dust that builds up when cutting, drilling or grinding material on the construction site can cause serious effects inside the body if exposed to for a long period of time [7][8][13][16].

F. Noise (NOS)

Frequent exposure to high level of noises either from the environment or from equipment can cause hearing damage [8][13][17][18].

G. Layout (LAY)

Inadequate space or difficult entry to perform a certain tasks was recognized as 15% of the accident studied therefore leading this to one of the major case whereby the delivery vehicle partially overturned due to the lack of sufficient room to extend the stabilizers [3][7][19].

H. Electrical hazard (ELC)

Electrical hazard causes 44% of all fatal electrical accidents from all industry. Mismanagement and poor protection of electrical system leads to fatalities [17][20][25].

I. Vibration (VIB)

Working with operating machine or equipment that

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vibrates at a high frequency could cause workers to become exhausted and stagnant [4][7][8][13].

J. Equipment design (DSG)

Appropriate tools design can eliminate common safety hazard [3][17].

K. Design of PPE (PPE)

Inappropriate PPE design may lead the workers not too wear PPE during their work. This, in turn, decreases work performance and creates health and safety hazard [3] [22][23] [27].

L. Quality of material (QLT)

Collapsing of building can be caused by poor material quality. Ransom et al., stated that poor quality of material causes accidents in construction industry [3][8].

M. Innovative technology (TEC)

Outdate equipment could cause ineffective work and injuries, as it cannot provide a suitable function for some specific [7][18][24][25].

N. Sub-contractor's equipment (SUB)

Subcontractor provides equipment machine and their employees to the construction company under the agreement to help them finish the project on time. Improper use of subcontractor's equipment could lead to construction accident [3][9].

O. Safety related budget (BUD)

Construction Company should provide enough budgets to support necessary safety-related activities [9][26][27].

P. Project duration (DUR)

In limited project time available, workers are force to work under pressure. This in turn, causes accidents [18][25][27][28].

Q. Customer satisfaction (PSR)

When Construction Company tries to meet the expectations of customer so as to satisfy them, pressure builds up leading to unexpected accidents, which should not happen [29][30].

R. Maintenance program (MTN)

According Ransom et al., tools and equipment in the construction site are not properly maintained. This could lead to serious accidents [3][7][8].

S. Safety training program (TRN)

Based on Sawacha et al., 2010, training program that does not match the nature of work, is meaningless [7][18][23][32].

T. Adequate provision of safety equipment (ADQ)

Many construction company in Thailand do not have enough PPE to provide to all of their employees when they come to work, therefore some worker needs to buy the PPE for themselves. PPE are also expensive and this leads to worker not buying it as they could not afford the safety equipment [3][27].

U. Work hours (SHF)

Based on Adane et al., 2013, accidents in the accidents in the construction site occur when workers work more than eight hours per day or 60 hours per week [27][33].

The above 21 attributes are used to develop questionnaire survey to collect data for further analysis.

III. Questionnaire Survey And Preliminary Analysis

The questionnaire survey was developed based on 21 attributes that influences construction accidents from a non-human error aspect. The questionnaire survey targets Construction Company in Bangkok and the target respondents were employee from both the management and management operation level in the company. The survey has two parts. The first part was about demographics and basic information of the respondent while the second part consists of 21 key attributes. A total of 255 questionnaires survey were sent, with 163 responses representing 63.92% return rate. Among those, 11 responses were unusable due to data incompleteness, resulting in the total of 152 questionnaires for the analysis. More than 70% of the respondents have been working in the construction industry for more than five years. Almost all mention that their organizations have safety policy, and around seven percent have reported that they received safety training. Around 50% of the respondents were engineers and the rest were managers and other. This shows the suitability of the respondents and the data collected.

Summaries of demographic information of the respondents are show in Figures 1.

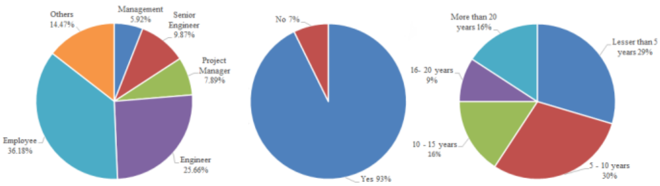

Fig. 1. (a) Experience in construction industry; (b) safety policy in organization; (c) position in organization

To further increase the certainty in the data collected, a series of preliminary analyses, including normality, and outlier tests were then executed to confirm that the data are appropriated. Normality test was used to confirm that the data is normally distributed and also to confirm that the data could be used. This includes the skewness and kurtosis measures while the outlier test includes 5% trimmed-mean, box plot, and z-score tests. The normality test result shows that all data have the skewness and kurtosis value within the acceptable range ±3 of ±7 and [34]. The outlier test result shows four datasets, which are 18, 16, 11 and 10, and one attribute with signs of outliers. They were therefore, removed from the data file. The remaining 148 data files and 20 attributes were used in exploratory factor analysis.

IV. Exploratory factor analysis (EFA)

EFA was used to extract the 20 attributes into groups to represent key factors representing root cause of construction accidents. For this research, principal axis factoring method, with eigenvalue more than one and together with varimax rotation and a loading factor of 0.4 will be used [35][36]. In the first run, as shown in Table 1, DUR, MTN and SHF were removed from the data, as they had values less than the acceptable loading value of 0.4.

TABLE I
FACTOR ANALYSIS RESULTING OF THE 20 ATTRIBUTES.

Attributes	Factors				
	1	2	3	4	5
DUS	0.63				
VIB	0.61				
NOS	0.59				
DSG	0.57				
ELC	0.57				
LAY	0.55				
PPE	0.49				
QLT		0.68			
SUB		0.66			
TRN		0.54			
TEC		0.49			
ADQ		0.43			
MTN					
SUN			0.65		
WTH			0.61		
VEN			0.57		
DUR					
LHT				0.75	
PSR					0.62
SHF					

In the final run, as shown in Table 2, all of the 16 attributes were divided into three factors. The first factor was named Ergonomics Design. This is partially confirmed by [4] that Ergonomics Design factors should include Light, Noise and Vibration. The second factor was named Supporting Policy and the third factor was named Environment. Both of these were also partially confirmed by [5] that Supporting Policy factors should include Training and Technology while Environment factors should include Weather and Sunlight.

TABLE II
FACTOR ANALYSIS RESULT OF THE 16 ATTRIBUTES

Attributes	Factor		
	1	2	3
ELC	0.71		
LAY	0.70		
DSG	0.65		
VIB	0.51		
PPE	0.50		
LHT	0.49		
NOS	0.43		
SUB		0.70	
QLT		0.63	
TRN		0.56	
TEC		0.50	
ADQ		0.05	
VEN			0.66
SUN			0.64
WTH			0.64
DUS			0.55

To reconfirm that the factors is reliable, Cronbach Alpha test was used. The results from the alpha test shows, Table 3, that the values of Ergonomics Design, Supporting Policy and Environment are 0.86, 0.8, and 0.76 respectively. This is within the acceptable range of 0.7 according to [37], is within the acceptable range. Structural Equation Modelling was then used to find the relationship between the three factors.

TABLE III
RELIABILITY TEST

Result Factors	Test Alpha
Ergonomic Design	0.86
Supporting Policy	0.8
Environment	0.76

V. STRUCTURAL EQUATION MODELLING (SEM)

The results from EFA were used in SEM to find the directional relationship between each key factor influencing construction accidents from a non-human error perspective.

A. Measurement model

The three key factors were used to find the relationship between each factor. The final run resulted in Figure 2.

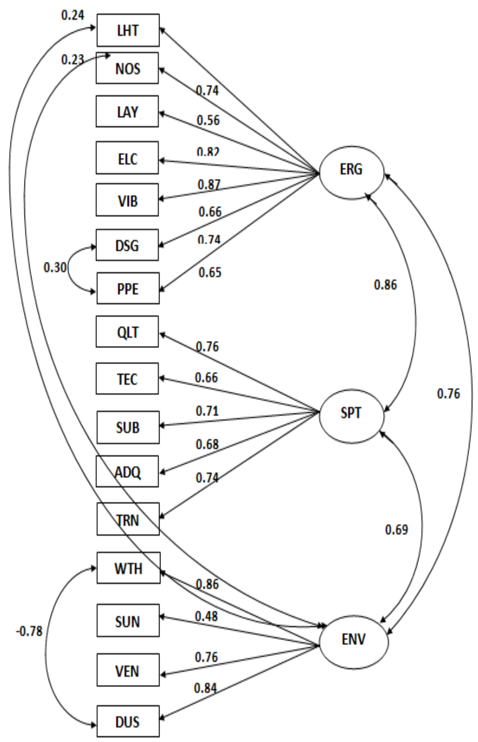

Fig 2: Fitted measurement model

B. Structural Model

Structural Model was constructed to find the directional relationship between the three key factors. Eight structural models with different directional relationship were constructed based on number of literature reviews. Out of all eight models, the best-fit model is shown below in Figure 3 that is the final run of the structural model.

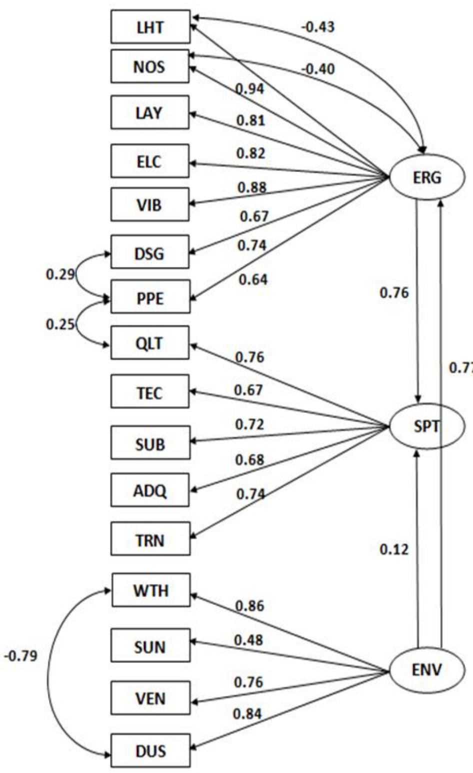

Fig 3: Fitted structural model

TABLE IV
OUTPUT OF FITTED MEASUREMENT MODEL AND STRUCTURAL MODEL.

Fit Indices	Recommended Criteria	Fit Measurement Model	Fit Structural Model
CMIN/DF	<2.00	1.96	1.76
CFI	>0.90	0.95	0.93
RMSEA	<0.08	0.07	0.07

Table 4 shows the values of CMIN/DF, CFI and RMSEA of the measurement model in their final run. The values of CMIN/DF, CFI and RMSEA of the structural model were within the acceptable range [30][38][39][40].

VI. CONCLUSION AND RECOMMENDATIONS

According to the rate of accidents when comparing to other sectors, construction industry fatalities is one of the highest. Therefore this research was conducted to investigate and find the root causes of construction accidents in terms of non-human error, their relationship, and suggest a possible solution in order to reduce the rate of accidents.

The research has shown that construction accidents can be caused by three key factors, which are Ergonomic Design, Environment and Supporting Policy. The structural model indicates that there are two possible ways to reduce construction accidents. To either focus on the ergonomics design or on supporting policy as environment is an uncontrollable factor. Construction Company should look to improve their policy or the ergonomics design so as to cope with the environmental factors.

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