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The Relative Factors Shaping Construction Workers' Behaviors and Leading to Accidents

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Abstract. Most construction workers' behaviors are shaped by task objective constraints and their capability during the operation. This research describes the construction workers' behaviors are an interaction between the task demand and the worker capability. The relative factors that influence construction workers' behaviors have been determined through the Delphi process and Analytical Hierarchical Process (AHP). The panel participated in these processes was represented by 9 safety experts who were specialized in high-rise building construction. Results of the analysis showed that 23 task demand factors and 12 worker capability factors were determined by 2 rounds of the Delphi process under the expert's consensus. The weights of these factors were determined by utilizing the AHP. The most weighted factor of the task demand was the Societal and Environmental Impact Awareness Factor. The Foreman's Communication Ability Factor was the dominant weighted factor of the capability. The factors and their relative weights can guide practitioners to manage the project resources safely and efficiently.

Keywords: Capability, construction safety, task demand, workers' behaviors.

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1. Introduction

Construction work involves a lot of work processes which are subjected to change according to project-specific requirements and contexts. The work environment is also changed abruptly as a dynamic condition. These changes create many chances of accidents and the raised statistical number of construction trade occupational injuries [1,2] and their consequences are loss of many lives, property damages, and a large amount of compensations.

Results from Haslam et al. [3] research showed that the main causal factors in construction accidents were problems arising from workers and bring into consideration of workers' behaviors while performing their tasks. Health and Safety Executives [4] research report also concluded that worker behavior is the main contributing factor in approximately 80% of the accidents. Moreover, the results from Kaila [5] study found that 80-95% of all accidents are due to unsafe behaviors and actions. Workers tend to overestimate their ability to control or prevent an accident, and this leads to an under-estimation of the risk and behaving unsafely intentionally [6]. It is usual that workers have to adjust their behaviors because of the production pressure for a faster work pace. These circumstances can cause a conflict between safety and productivity which in the short term are usually resolved in favor of production [7].

Accordingly, Rasmussen [8] proposed a descriptive model of work behavior which explains how the workers' behaviors tend to migrate closer to the boundary of functionally acceptable performance. These behaviors are caused by two primary pressures: the management pressures for increased efficiency of production and the tendency for less effort which is a response to an increased workload. During the adaptive search the workers have ample opportunities to identify 'an effort gradient' and management will normally supply an effective 'cost gradient'. The result will be likely to be a systematic migration toward the boundary of functionally acceptable performance and, if crossing the boundary is irreversible, an error or an accident may occur [8].

Rasmussen's principle is grounded in Cognitive System Engineering (CSE) which is concerned with the characteristics of the work system that influence the decisions, behaviors, and the possibility of errors and failures. [9] Cognition emphasizes that work performance depends on interacting between the workers and the characteristic of work system [10]. Cognitive theories can explain not only individual's behaviors but also the other impact factors from outside environment [11]. Most applications of CSE to safety management are related to high-risk operations in complex systems, such as aviation, health care, nuclear and chemical plants. In the area of construction safety, Saurin et al. [12] have implemented and examined site safety practices from the cognitive perspective. They also suggested research opportunities for devising innovative construction safety management systems which were based on three core principles of CSE, namely flexibility, learning, and awareness.

Construction is a loosely coupled work system and leaves many degrees of freedom for the worker crew [13]. It is only a suggested workflow but is not required to follow all the steps which leave some spaces for the workforce to consider an appropriate choice of working decisions under dynamic situations [12]. These situations make the workers' behaviors migrate closer to the boundary of functionally acceptable performance and working in the boundary of error margin.

The implementation of safety rules and a safety campaign in the construction trade is mostly prescribed "safe behaviors" to keep workers' behaviors away from the boundary of functionally acceptable performance [14]. However, the applied pressures are still pushing workers toward that boundary. This normative approach of construction safety focuses on prescribing and enforcing the safety rules, and defends workers' exposure to hazards. Under this perspective, accidents still occur due to lack of safety knowledge and/or commitment. Moreover, the development of construction technology and construction safety has been improved, [15] thus human adaptation compensates for these safety improvements and tries to get closer to the boundary of functionally acceptable performance again. This phenomenon has been observed in traffic research and explains why technological safety improvements have not generated the expected improvement outcomes in safety [9].

The characteristics of traffic change all the time [16]. This dynamic circumstance is similar to the changes in construction. With regard to traffic accidents, the Task Demand-Capability Interface (TCI) model [9] provides a new conceptualization of the process by which collisions occur. At the heart of the TCI model is the relationship between the task demand and the capability applied to achieve a safe outcome while driving a vehicle. When the task demand is less than the capability, the driver has a control of the situation. When the task demand is greater than the applied capability, the result is loss of control. This situation may result in a crash or may not, if there is a compensatory action by others. Thus, to maintain the control, it is necessary that the driver anticipate the task demand and match it with the suitable capability.

The TCI model is based on the cognitive perspective and linked with the Rasmussen principle of the workers' behaviors. The task demand can be interpreted as the management pressures that try to succeed with the goals under limited conditions. For capability, it is derived to worker's effort gradient which depends on physical and mental attributes.

The feasibility of applying the TCI principle in construction safety research has been demonstrated by Mitropuolos and Cupido [10] research. They synthesized a new safety model which displayed an interface between the demand of task and the capability applied during working. The model showed the relationship between task demands and applied capabilities that shaping the workers' behaviors and then the likelihood of accidents. From this view, it can be drawn that the unsafe behaviors of construction workers are initiated by the attributes of task demand and capability. Hence, a research gap is addressed on the actual combination of task demand and worker capability which contribute to unsafe actions and consequent accidents, and the relationships among these factors.

The previous research has revealed that workers' behaviors systemically migrate to the risk condition all the time by attributes of the task demand and capability. The forthcoming model should be considered for the attributes that crate the workers' behaviors in a dynamic environment. The existing construction safety models seem to be insufficient. They are mostly based on the normative approach which ignores how the characteristics of the task and the worker capability influence the possibility of errors and accidents. The task demand and the worker capability are being highlighted as the initial causes of unsafe actions. The objectives of this paper are to determine task demand and capability attributes that influence workers' behaviors and then to determine the relative weights of these attributes which contribute to the likelihood of an accident in construction trade.

2. Materials and Methods

2.1. Framework for Model Development

Worker's behaviors tend to getting close to the error margin all the time. The cognitive theory has ability to describe worker's behaviors in the proper way. All the unsafe actions are generalized by two main attributes. The first one is management pressure as we know as the Task Demand (TD). The second one is the tendency for least effort which namely as Capability (C). Whereas TD is defined as the difficulties in completing the task according to its target, C is defined as the worker's abilities to handle the task demands. It would be worthwhile to develop a practical model from task demand and capability attributes that can forecast an accident. The combination of model components must be investigated along with finding the relative weight of each component. This procedure is detailed in this paper as phase 1 of the research framework.

The Delphi process has been applied to determine the model components or factors. Safety is one of the subjective research topics whose data collection is mostly relied on opinion survey and group-brainstorming techniques. All substantial involving bias must be recognized and minimized [17]. The advantage of the Delphi process is to decrease the variability of the responses and achieve group consensus about the correct value. Consensus is built by using a series of questionnaires administered in various rounds [18]. Four key features of the Delphi process are anonymity, iteration, controlled feedback, and the statistical aggregation of group response [19]. The Delphi process is intended for use in judgment and forecasting situations in which pure model-based statistical methods are neither practical nor possible [20]. The Delphi process which is proposed in this study offers the opportunity to control dominant biases through anonymity, and elicit practical data that really reflected on the current construction safety situation. It requires a moderator and a panel of experts who are qualified and approved. The experts are anonymous and participated individually in two or more rounds of the structured questioning.

Also, this research implemented AHP which is initiated by Saaty's [21] to find the relative weights of these model factors. These weights express a degree of importance of each factor relative to the others [22]. The overall index of these factors can be computed accordingly that will objectively and realistically reflect the level of ongoing safety [23]. The major advantage of AHP is its capability to check and reduce the inconsistency of expert judgments. While reducing bias in the decision making process, this method provides group decision making through the consensus [24].

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Phase 2 of the research is to analyze the relationships between these factors and the likelihood of an accident using Multiple Linear Regression (MLR) and Artificial Neural Network (ANN) methods. Finally, a construction workers' behaviors model for accident prediction will be developed as shown in Fig. 1.

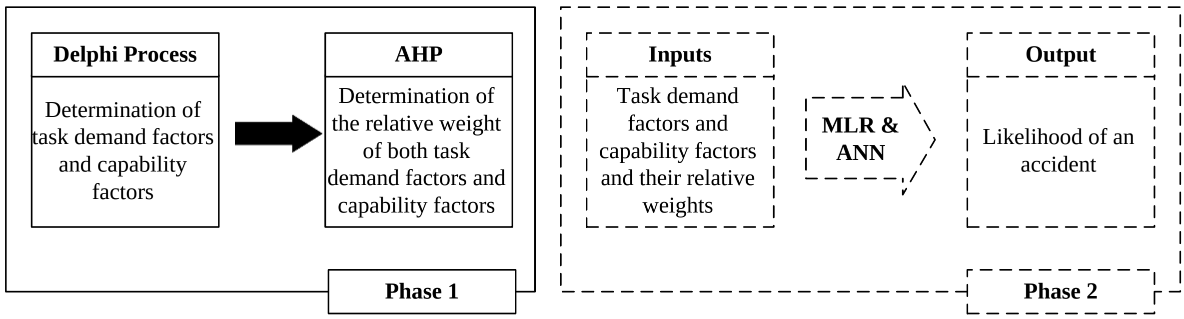

Fig. 1. The research framework of model development.

2.2. Components of Proposed Model

The proposed model consists of two main parts TD and C. TD includes physical demands and cognitive demands which push workers into the risk condition. TD can be divided into three groups, namely Task Factors, Environmental Factors, and Work Behavior Factors. All these groups are further broken down into a total of 23 factors. For the other part, C can be divided into four groups, namely Competence Factors, Human Factors, Attention Factors, and Foreman Factors which are further decomposed into a total of 12 factors. All these 35 factors are extracted and drawn on the existing literature in [3, 10, 25], and they are also resulted from the pilot survey by 9 safety experts in high-rise building construction projects. The 9 experts involved with this stage certified as either professional safety or administrational safety with a lowest of 6 to a highest of 23 years of construction safety experiences. The pilot survey was conducted consisting of open-ended questionnaire about what are the relative factors of TD and C. This questionnaire is provided the guideline of 17TDs and 9Cs factors which derived from the underlying prior literatures. Figure 2 shows the category of all factors of the proposed model which 6TDs and 3Cs factors are resulted from the pilot survey.

A group of Task Factors includes characteristics of the assigned task. They consist of the following factors.

- Task Complexity (TD1): It describes the complexity of the task and the level of workers' skills required.
- Transportation of Material (TD2): It describes the requirement of moving materials from the storage location to the working place and the involvement of machine or equipment for this transportation.
- Work Coordination (TD3): It describes the coordination among different trades required in the task. If more trades are involved, the task becomes more difficult.
- Required Working Space (TD4): It describes the adequacy of the available working space compared to the requirements.
- Type of Main Material (TD5): This factor accounts for the type of main materials which are used in the task. It can affect the workability of the task. For instance, low slump concrete is required for casting a shear wall. In this situation, the type of main materials creates a more difficult task when compared to typical specifications.
- Machines/Equipment (TD6): This factor accounts for the requirements of complicated or heavy machines and/or equipment for the task.
- Tools (TD7): Similarly to the former factor, this factor accounts for the requirements of specials personal tools for the task. A task which requires many special tools is implied to be more difficult than the ordinary.
- Building Design (TD8): The design of the building can account for the difficulty of the overall project and so the task.
- Construction Methods (TD9): Not only the design, the construction methods used can also impact the difficulty of the task. The worker works uneasily with the unfamiliar methods.

- Engineering Tolerances (TD10): This factor describes the allowable tolerances applied to the task. The acceptable deviations in measured values, dimensions, or properties of the work can affect the difficulty of the task.
- Finishing-Work Quality (TD11): It accounts for the acceptable qualities of architectural works and the finishing-work. Whether or not the task requires a higher or lower quality than a typical one.

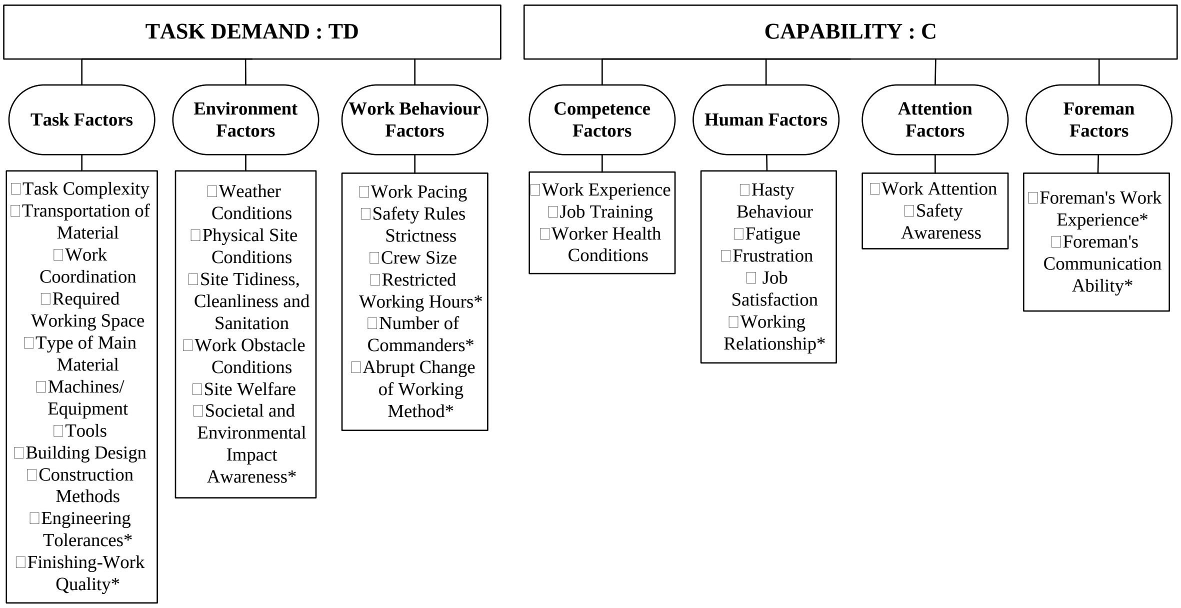

Fig. 2. Elements of task demand and capability. (*Factors added from the pilot survey.)

A group of Environmental Factors refers to the site conditions that workers are confronted with. These conditions are various and can impact the task demands.

- Weather Conditions (TD12): This factor describes the weather conditions during the task execution. Uncomfortable weather conditions such as windy, rainy, humid, and hot can increase the task difficulty.
- Physical Site Conditions (TD13): This factor describes the physical site conditions including noise, lighting and ventilation inherent during the task operation. Inappropriate levels of these physical conditions can discomfort workers.
- Site Tidiness, Cleanliness and Sanitation (TD14): This factor describes the quality or condition of being neat in construction site, along with adequate sanitation. The poor conditions increase the difficulty of the task and the potential for errors.
- Work Obstacle Conditions (TD15): This factor accounts for the interference of some other works nearby which sometimes require workers' attention or response and can increase the difficulty of the task.
- Site Welfare (TD16): This factor accounts for the sufficiency of the welfare provided on site such as drinking water, toilets and rest area. This welfare can help comfort and refresh workers when needed.
- Societal and Environmental Impact Awareness (TD17): This factor describes the awareness of societal and environmental impact on the neighborhood. The workers' attentions are required to minimize this impact especially when the project site is situated at a sensitive area.

A group of Work Behavior Factors is related to pattern of actions and interactions of the members that affects its effectiveness. It consists of these factors.

- Work Pacing (TD18): This factor depends on the available time to complete the task. If the project is delayed, the catch-up plan has to be implemented and the task becomes more difficult.
- Safety Rules Strictness (TD19): This factor depends on how safety rules are applied in the site. All workers must comply with the safety rules and guidelines, and should not do anything to endanger themselves and other persons. If all the safety rules are not enforced strictly and rigorously, the task would be difficult.

- Crew Size (TD20): This factor refers to a proper number of workers that are required to perform the task. If insufficient workers are assigned, the task becomes difficult.
- Restricted Working Hours (TD21): This factor refers to the period of time that can be spent at the construction project. The limited number of working hours made the task more difficult because the workers try to finish their work within a limited time.
- Number of Commanders (TD22): This factor accounts for number of headman who assigns workers. More than one headman can cause workers confused and the task gets harder to perform.
- Abrupt Changes of Working Method (TD23): This factor refers to unexpectedly sudden changes in working method. These changes can also cause task difficulty.

A group of Competence Factors is related to the overall workers' competence which includes work experience, job training and health conditions.

- Work Experience (C1): This factor describes the level of work experience of a worker that is related to the current task. It directly affects on his/her capability.
- Job Training (C2): This factor describes the level of job training or educating of a worker through which his/her competence can be developed.
- Health Conditions (C3): This factor accounts for workers' health conditions such as chronic condition, sickness and substance abuse which can decrease capability.

A group of Human Factors which expresses five key states of mind of workers including haste, fatigue, frustration, job satisfaction and working relationship.

- Hasty Behavior (C4): This factor describes the hastiness of workers' behaviors. The hasty or sluggish behavior while operating the task can vary the capability.
- Fatigue (C5): This factor refers to the extremely tiredness, typically resulting from mental or physical exertion or illness. Fatigue can be caused by the exceeding working hours and it continues for several days.
- Frustration (C6): This factor is related to the feeling of being upset or annoyed. Workers could get frustrated from the job or personal matters. If workers get frustrated with both matters, their capability can decrease.
- Job Satisfaction (C7): This factor refers to the feeling and the pleasure derived from job. Job satisfaction and job attitude can increase or decrease capability.
- Working Relationship (C8): This factor describes the state of being connected with the co-worker. Since construction work involves several workers, the coordination between co-workers is essential for better performance.

A group of Attention Factors is related to workers' attention and awareness. Attention is an interest and carefulness that workers show in their work. It is a limited resource, and it can be reduced as workers perform multiple tasks;

- Work Attention (C9): Loss of attention to work brings worker to the risk condition due to capability being decreased. Working under unconscious conditions is not recommended.
- Safety Awareness (C10): If workers are aware of all safety practices and measures during their work execution, capability can be increased. Keep vigilant all the time is recommended.

A group of Foreman Factors is related to the foreman's work experience and communication ability. Foremen play a main role to support their crew capability. Subsequently, capabilities of a worker are influenced by these factors.

- Foreman's Work Experience (C11): This factor accounts for the work experience of the foreman. An experienced and competent foreman can effectively train and guide his/her crew. The more work experiences the foreman has, the more workers' capability can be increased.
- Foreman's Communication Ability (C12): This factor describes the ability of communication of the foreman which is necessary for making a successful interaction with his crew. The communication ability also ensures that all instructions are well understood. This factor is very important in case of the migrated workforces.

2.3. Expert Panel

The panelists participated in the Delphi and AHP consists of 9 construction safety experts who are highly experienced on high-rise building construction. One of the main advantages of the Delphi technique is that there is no requirement for a minimum number of panelists in the survey. However, it should be adequate to draw an acceptable conclusion at the end of the process [26]. Rowe and Wright [20] indicated that the size of a Delphi panel has ranged from a low of 3 to a high of 80 members. The specific number of panelists should be dictated by the characteristics of the study such as the number of available experts, the desired geographic representation, and the capability of the facilitator [17]. Therefore, the decision-making group probably should not be too large, i.e. a minimum of 5 to a maximum of about 50 [27], the Delphi technique work group of 5 to 9 members are sufficient [28]. In addition, there is no minimum number of experts in the AHP. The AHP is meant to help an individual to organize his thinking and deal with many decisions. The process allows him to experiment with different criteria and different judgments [29]. Some research studies applied a combined Delphi and AHP and utilized the same panel of experts for both processes [30, 31]. The Delphi was employed at the preliminary stage in order to shortlist and identify the prominent variables. The AHP was then employed at the subsequent stage to determine the relative weights of the selected variables [32].

Therefore, this study invited 9 experts to participate for both processes. These experts are not the same group as recruited in the pilot survey. The validity of the proposed factors heavily depends on the qualifications of this expert panel. The expert qualifications are summarized in Table 1.

Table 1. Expert qualifications.

Work Position	• Two of them held project director position and committee of safety and health at work promotion association (Thailand).
	• Four experts occupied as a safety manager and another three experts held position as senior safety officer.
Safety Certification	• Eight of them certified as professional safety and six of them certified as administrational safety.
Education	• Education level of eight experts started from bachelor to master degree and one expert graduated from higher vocational certificate.
Experience	• These nine safety experts had a cumulative 140 years of construction safety work experience.
Training	• Totally more than 1,700 hours of safety training courses.
Instructor	• Eight of them are safety at work instructors for their company and two of them have been invited as instructor for external agencies.
Author	• Eight of them are author of safety management handbook for their companies and two of them are committee of department of labour protection and welfare who issued a construction safety manual.

2.4. Factors Determination by the Delphi Process

The Delphi process helps identify and validate the significance of all proposed TD and C factors. The insignificant factors will be removed from the final lists through the experts' consensus. The experts were asked to rate the significant level of the proposed factors in a 5-point scale. The values 1, 2, 3, 4 and 5 represented the linguistic terms as least, less, moderate, high and highest significances, respectively. At the beginning of the next round, the moderator provides an anonymous summary of the experts' responses from the previous round. Then, the experts are encouraged to revise their own previous responses according to the revealed group's result. The revision keeps continue on the next round and so on. The criterion for terminating the process is the group interquartile range (IQR). When the group interquartile ranges of all factors are less than or equal to 1.50, the group consensus is achieved and the Delphi process can be ended. Any factors which receive a group median less than 3.00 are considered as insignificant and must be removed. The other factors receiving a group median more than or equal to 3.00 are included in the final list because the experts consentaneously consider them at least as a moderate significant level factor.

The Delphi procedures are displayed as Fig. 3 and can be detailed as following lists;

1. A five-point scale was coded to define the significance of all proposed TD and C factors.
2. The obtained responses were analyzed using median and IQR refer to Eq. (1), (2), and (3). These results and some feedbacks (if necessary) were declared at the end of each round.

3. All IQR of each factor required must be ≤ 1.50 to achieve the group consensus. Otherwise, another round of the process is needed.
4. After the group consensus is reached, the median values are considered. The factors that occupied group median of more than or equal to 3.00 will be integrated in the final list, and the rest factors will be removed as the insignificant factors of proposed model.

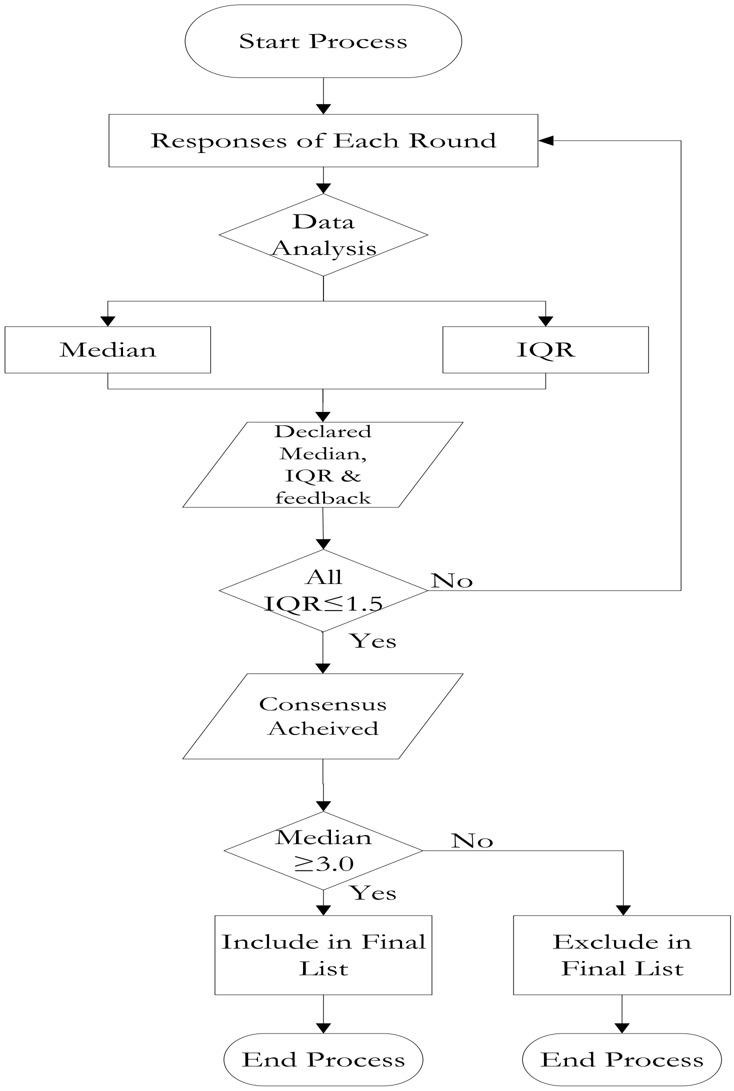

Fig. 3. The procedure of Delphi process for determining the significant factors.

The median and interquartile ranges are calculated by using the following equations [33]:

Median

$$\text{Median} = L + w(0.5n - cfb)/fm \tag{1}$$

where L = lower class limit of the interval that contains median
n = total frequency
cfb = the cumulative frequencies before the median class
fm = frequency of the class interval containing the median
w = interval width

Interquartile range (IQR)

$$\text{IQR} = Q_3 - Q_1 \tag{2}$$

Q_1, Q_3 calculates by,

$$Q_i = L_{Qi} + ((n * i)/4 - cfb)w/f_{Qi} \quad (3)$$

where i=the ith quartile

L_{Qi} = lower class limit of the interval that contains ith quartile median

n = total frequency

cfb = the cumulative frequencies before the ith quartile median class

f_{Qi} = frequency of the class interval containing the ith quartile median

w = interval width

2.5. Weighting Factor by AHP

The same panel was also participated in AHP including 9 construction safety experts. The extracted data from surveying have been analyzed by three processes: pair-wise comparison, relative weight computation and consistency ratio calculation. The details of each process are described as follows.

The first process is the pair-wise comparison. All attributes are listed in both rows and columns to form a comparison matrix. These attributes are then pair-wise compared. During the comparing process, the participants must answer two questions 1) which of the two attributes in the set is more important or has a greater influence on the attribute located one level above in the hierarchy? And 2) what is the intensity of that difference in terms of importance or contribution? The verbal assessments are interpreted into quantitative scale referring to AHP 1-9 scale (e.g., 1 = equal importance, 3 = moderate importance, 5 = strong importance, 7 = very strong importance, and 9 = extreme importance). Integers in the comparison matrix that is greater than 1 means that the attribute in the row has a higher degree of importance than the attribute in the column

The second process is the relative weight computation. The Saaty's core theorem states that the eigenvector of the comparison matrix is a local priority vector of the attributes compared. There are several approximation methods used to compute the eigenvector ($\vec{w}$), of which the average of normalized columns (ANC) method is the most accurate [34]. w_i is the relative weight of the attribute in row i and it is an element of the eigenvector $\vec{w}$ for a reciprocal $n \ x \ n$ matrix. The ANC computation of w_i is as follows:

$$w_i = (\textstyle\sum_{j=1}^{n} a_{ij})/n \quad (4)$$

where a_{ij} = the element located in row i and column j of the normalized-column matrix.

The third process is the consistency ratio calculation. The consistency ratio: CR is a measure for controlling the consistency of the pair-wise comparisons [35]. Saaty [34] introduced a formula to compute CR. The CR value should not be more than 0.10; otherwise, the pair-wise comparison or the hierarchy of the structure has to be revised. The acceptable CR does not guarantee that the values of attribute weights are correct. Instead, it ensures that no intolerable conflicts exist in the comparison process or the relative weights are logically sound and not a result of random prioritization.

Table 2 is illustrated an example of above computation procedure and can be detailed as follows.

There are three factors to be compared with respect to "Task Demand". The three factors are TF = Task Factor, EF = Environmental Factor, and WF = Work Behavior Factor. The matrix 3 by 3 is crated as it has three sets of attributes to be compared. The diagonal elements of the matrix are always 1, and it only needs to fill up the upper triangular matrix. The upper triangular matrix needs to fill by the actual judgment values on the left side of 1. To fill the lower triangular matrix, just use the reciprocal values of the upper diagonal. For example, a comparison between Environment Factor: EF and Work Behavior Factor: WF (EF/WF) was given as 7. It meant that EF had more influence on Task Demand than WF with very strong importance intensity. Also, it was implied that WF/EF was equal to 1/7. Then sum each column of the comparison matrix.

Each element of the matrix is divided with the sum of its column, then we have normalized-column matrix. The sum of each column is 1. The relative weights of each factor are displayed as eigenvectors. The eigenvectors are calculated by Eq. (5). Hereby, the relative weight of TF, EF, and WF with regard to the Task Demand are 0.283, 0.643, and 0.074 respectively.

Table 2. The example of comparison matrix and normalized-column matrix according to "Task Demand".

Com parison	**TF**	**EF**	**WF**	**Normalized -Column**	**TF**	**EF**	**WF**	**Row sum**	**Eigen vector**
TF	1.00	1/3	5.00	TF	0.24	0.23	0.38	0.85	**0.283**
EF	3.00	1.00	7.00	EF	0.71	0.68	0.54	1.93	**0.643**
WF	1/5	1/7	1.00	WF	0.05	0.10	0.08	0.22	**0.074**
Column sum	4.20	1.48	13.00	Column sum	1.00	1.00	1.00	3.00	1.000
Eigenvalue (λmax)								=	3.0655
Consistency Index (CI)								=	0.0328
Ramdom Index (RI)								=	0.5800
Consistency Ratio (CR)								=	0.0565

Aside from the relative weight, the consistency of the results is verified. The eigenvalue (λmax) is obtained from the summation of products between each element of eigenvector and the sum of columns of the comparison matrix. The consistency index (CI), random index (RI) and consistency ratio (CR) are calculated refer to Saaty [34]'s formula. The consistency ratio is 0.0565 which less than 0.10, and implied that no intolerance conflicts exist during the comparison process.

3. Results and Discussion

After comprehensive analysis, the results of this research are divided into 2 main parts as follows.

3.1. Results of the Delphi Process

The procedure of the Delphi process and the definition of all 35 proposed factors were thoroughly explained to the expert panel. The experts were asked to rate the relevance of each factor by using the five-point scale. The Delphi process was actually finished in two rounds. The detailed results of the Delphi process are shown in Table 3 and 4.

For TD Factors, in the first round of the Delphi process, all group medians were higher than 1.50. The 8 factors had IQRs more than 1.50 so that the group consensus did not achieve yet and the second round was required. In the second round, all group medians were still higher than 1.50 and all IQRs were under 1.50. The group consensus was reached and the process was ended. The final results were that none of the 23 factors (TD1-TD23) were removed. The highest group median was TD2-Transportation of Material Factor with 4.75. The lowest group medians were both TD16-Site Welfare Factor and TD21-Restricted Working Hours Factor with 3.00.

Table 3. Determination results of task demand factors by the Delphi process and weighted factors by AHP.

Delphi							AHP
Categorised Factor	Factor		Round 1		Round 2		Weighted
			Median	IQR	Median	IQR	
Task Factors 35%	TD1	Task Complexity	3.75	1.69	4.00	1.50	3%
	TD2	Transportation of Material	3.75	3.13	4.75	0.88	3%
	TD3	Work Coordination	3.60	1.13	3.86	0.64	2%
	TD4	Required Working Space	3.13	1.69	3.38	1.27	3%
	TD5	Type of Main Material	2.88	2.19	3.75	1.00	2%
	TD6	Machines/Equipment	4.40	0.99	4.06	0.56	2%
	TD7	Tools	4.33	1.35	4.40	0.99	2%
	TD8	Building Design	3.88	1.69	4.38	1.13	5%
	TD9	Construction Methods	3.88	1.31	4.20	1.00	8%
	TD10	Engineering Tolerances	3.38	1.94	3.60	0.99	3%
	TD11	Finishing-Work Quality	3.13	1.31	3.60	0.99	2%
Environment Factors 35%	TD12	Weather Conditions	3.60	1.43	3.75	0.88	5%
	TD13	Physical Site Conditions	3.80	1.50	4.08	0.75	6%
	TD14	Site Tidiness, Cleanliness and Sanitation	4.60	1.13	4.60	0.99	8%
	TD15	Work Obstacle Conditions	4.60	2.13	4.25	0.88	4%
	TD16	Site Welfare	3.00	0.90	3.00	0.50	2%
	TD17	Societal and Environmental Impact Awareness	4.25	2.19	4.33	1.35	10%
Work Behaviour Factors 29%	TD18	Work Pacing	4.20	1.00	4.40	0.99	7%
	TD19	Safety Rules Strictness	4.00	0.90	4.40	0.99	6%
	TD20	Crew Size	3.25	1.00	3.25	0.88	3%
	TD21	Restricted Working Hours	2.80	1.50	3.00	1.50	4%
	TD22	Number of Commanders	3.08	0.75	3.25	0.88	4%
	TD23	Abrupt Changes of Working Method	3.40	1.43	3.94	0.56	6%

For C Factors, in the first round of the Delphi process, all group medians were higher than 1.50. The three factors had IQRs of more than 1.50, so that the group consensus did not achieve yet and the next round continued. In the second round, all group medians were still higher than 1.50 and all IQRs were under 1.50. The group consensus was reached and the process was ended. The final results were that none of the 12 factors (C1-C12) were removed. The highest group median was C2-Job Training Factor with group median 4.40. The lowest were C4-Hasty Behavior Factor, C8-Working Relationship Factor, and C9-Work Attention Factor with the same group medians 3.40.

For both TD and C grouped factor, the Delphi process was ended by two rounds and reached the consensus with IQR under 1.5 and without any feedbacks. This finding further reinforced the consensus within two rounds of survey among the group of expert. This finding is consistent with the previous studies that have shown that generally 2-3 iterations are enough to specify the results [18, 36, 35].

The results indicated that none of the 35 proposed TD and C factors were removed The reason was that all these 35 factors were carefully pre-selected from the literature reviews and the authors' self-preliminary surveys of construction projects in Bangkok, Thailand. These pre-surveys resulted in a developed questionnaire with the proof of validation.

3.2. Results of AHP

AHP was implemented to find the relative weights of those 35 factors. It helped evaluate the degree to which each factor affecting the proposed model and identify the major contributing factors. The same expert panel was asked to do pair-wise comparisons using a 1-9 scale on those factors. The results have been analyzed and were tabulated in Tables 3 and 4.

Table 4. Determination results of capability factors by the Delphi process and weighted factors by AHP.

Delphi								AHP
Categorised Factor		**Factor**		**Round 1**		**Round 2**		**Weighted**
				Median	**IQR**	**Median**	**IQR**	
Competence Factors	21%	C1	Work Experience	3.80	1.00	3.94	0.56	7%
		C2	Job Training	4.40	0.99	4.40	0.99	7%
		C3	Health Conditions	3.67	1.35	3.80	1.00	7%
Human Factors	36%	C4	Hasty Behaviour	3.33	1.50	3.40	0.99	7%
		C5	Fatigue	3.75	1.38	3.94	0.56	7%
		C6	Frustration	4.00	1.63	4.20	1.00	6%
		C7	Job Satisfaction	3.38	1.27	3.60	0.99	9%
		C8	Working Relationship	3.33	1.50	3.40	0.99	7%
Attention Factors	22%	C9	Work Attention	3.13	1.19	3.40	0.99	11%
		C10	Safety Awareness	4.00	2.02	4.00	1.50	11%
Foreman Factors	21%	C11	Foreman's Work Experience	3.80	1.00	3.86	0.64	9%
		C12	Foreman's Communication Ability	3.88	1.69	4.10	0.80	12%

For the relative weights of TD factors, the top 3 highest relative weights were as follows:

TD17-Societal and Environmental Impact Awareness Factor received the relative weight with 10%. The experts pointed out that all high-rise building construction projects had to get Environmental Impact Assessment (EIA) approval before project is started. This requirement increased TD. Additionally, some activities might create environmental impacts during the construction process, such as dust or noise pollution to neighborhood. These environmental impacts increased the difficulty in completing the project. Based on Rajendran et al. [38] research, that has been studied of the impact of green building design and construction practices on construction worker safety and health. The results have shown little or no difference between green and non-green projects in terms of safety performance and a question arises as whether Leadership in Energy and Environmental Design (LEED) buildings should be labeled as sustainable buildings or not.

TD9-Construction Methods Factor was realized that it could increase TD. For instance, a method which involves working in the confined space might create more TD or more difficulty to perform the task. This factor came up with 8% of the relative weight. This finding corroborates the Everett [15] research that has emphasized the overexertion injuries in construction are caused by the prescribed tools and work methods.

TD14-Site Tidiness, Cleanliness and Sanitation Factor occupied 8% of the relative weight. An unclean or untidy work environment is a source of dangers and creates hazards to workers. This result is supported by Sawacha et al. [39] study that found a tidy site and well layout site were more likely to provide a high level of safety performance.

The least weighted factor nominated to TD11-Finishing-Work Quality Factor with 2% of the relative weight. The experts suggested that the high-rise building construction projects were highly competitive and they required quite similar standards of finishing work quality. This factor consequently did not influence TD much.

For the relative weights of C factors, the top 3 highest relative weights are C12-Foreman's Communication Ability Factor, C10-Safety Awareness Factor, and C9-Work Attention Factor with 12%, 11%, and 11% of the relative weights, respectively. The experts indicated that the C12-Foreman's Communication Ability Factor was the major factor affecting C and corresponding to the finding of Loushine et al. [40] study which observed communications as the second most frequently studied success factor in the previous literature. The communication contributes to successful quality and safety programs in construction. Most construction projects used a lot of foreign workers to operate the tasks. Communication abilities of foremen are really needed to supervise them. Moreover, the effectiveness of communication helped transfer foremen' instructions and knowledge to their workers precisely and completely.

The experts pointed out that the C10-Safety Awareness Factor was very important. Construction work is very dangerous. Workers must be aware of all safety practices and measures and remind themselves of any dangers all the time and do not taking any risks. Risk-taking behavior leads workers to be considerably more accident prone [41]. This safety awareness could strongly contribute to the increase in C.

C9-Work Attention Factor highly influenced worker's capability because the attention of a worker is a limited resource. Multiple tasks, teases, or other distractions grab workers' work attention and reduce C. Hinze's distraction theory [42] detailed how the concentrate on the production task can act as a distraction from the hazard.

The least effect factor on C is C6-Frustration Factor with 6% of the relative weight. The experts realized that frustration during the task has little influence on C.

4. Conclusions

Recent research argues that workers' behaviors are always getting close to the risk condition. Despite having the necessary improvement of safety condition or safety technology, workers frequently choose to violate safety rules, procedures or not use protective equipment for their own proposes [43]. Therefore, it is wise to discover the influencing factors of these workers' behaviors which consequentially result in unsafe actions and potentially lead to an accident. This study applied the Delphi process and AHP to discover the task demand (TD) and capability (C) factors and their relative weights that influencing workers' behaviors. The 9 safety experts of high-rise building construction in Thailand were recruited in both processes. After reaching the consensus among the expert's opinions of two rounds of the Delphi process, the results indicated that all 35 proposed factors received the group median over 3.0 and they were absolutely inevitable to model components. These factors could be generalized for high-rise building construction projects but the other scenarios could be applied with more or fewer factors. The results from AHP showed the relative weights of these factors which indicated their significance levels. Furthermore, they could be used to prioritize the management's concerns and plan an effective strategy. Project managers can concentrate on certain factors instead of handling all the factors to succeed the project safely and efficiently. The future research is necessary to better understand a link between these factors and the likelihood of an accident which can be proved through the empirical data. The construction workers' behaviors model for the accident prediction will be further developed in phase 2 and the soundness of the model must be validated.

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