A Confirmatory Factor Analysis Of Vulnerability Of Construction Project To Fall Accident

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Abstract

Fall accidents are a primary cause of construction injuries. Therefore, strategy to prevent fall accidents must be a priority to many parties. A comprehensive understanding on factors, which cause a construction project to be vulnerable to fall accidents and the causality relation of the factors, is required in determining an effective strategy to prevent fall accident. The objective of the paper is to test the conceptual model of the factors that cause vulnerability leading to fall accidents in construction project against empirical models. The model describes the structure of the causal relationship of factors that cause vulnerability leading to fall accidents in high-rise building construction project. The conceptual model was developed based on review of the relevant theory and research literature to support the model. The empirical model is conducted by analyzing of data from 100 respondent perception that a safety officer in construction projects. The paper utilizes the Confirmatory Factor Analysis/ CFA to analyze the a hypothetical model, that describes relationship 5 causes of vulnerability to fall accident include human factors, equipment factors, organizational factors, management factors and environmental factors.

Supported by empirical evidence, the study established that firstly, there are human factors, equipment factors, organization factors, management factors, and environment factors proven to be a cause of construction project vulnerability toward fall. This is shown by empirical model test result of the factors causing vulnerability of a project toward fall, which gained a good fit with conceptual model, with Chi Square value 2.78, P-Value = 0.83644 ($\geq$0.05), df = 6 (positive), RMSEA value = 0.000 ($\leq$0.08), GFI value = 0.99 ($\geq$0.90). Environmental factor is a very significant influencing factor on vulnerability level in which the lambda (λ) = 0.36 ($\geq$ 0.30), compared to equipment factor with lambda (λ) = 0.16, organization factor's lambda (λ) = 0.03, human and management factors with lambda (λ) = 0 10.

Keywords: Confirmatory Factor Analysis (CFA), Vulnerability, Fall accident, and Construction project.

1. Introduction

Statistic analysis in several countries concludes that risk of occupational accident in construction industry is significantly higher if compared to the average of all sectors (Kamardeen, 2009). In developing countries, the number of accidents in construction industry is much worse (Koehn, 1995). The construction industry is always risky because of outdoor operation, working at height, unskilled labor, and often working in dynamic and challenging, and complex environment (Hu 2009; Ismail, 2008).

Falls are a significant public health risk and a leading cause of non-fatal and fatal injuries among construction workers worldwide (Hu et al, 2011). In the construction project, falls are the major sources of accidents resulting in fatalities (Joylene, 2009). Fall accident is the major sources of accidents resulting in fatalities (Huang et al., 2003). According to NBS (2000-2008) fall accident cases in China are still the highest type of accidents compared to other types of accidents (Zou, 2009). In Hongkong, 47% of fatal accidents happened due to fall accidents (Chan, 2008). In America (1996 – 2006), fall accidents in building projects reached 32% of accidents that commonly ended with death (Dong et al., 2009). According to Ardan (2005), fall accident from the high-rise building projects is the highest accidents happened in Indonesia. In Taiwan, more than 30% accidents in building projects are fall (Chi, 1997). Sixty-nine percent of fall were from buildings project happened in New Zealand (Buckley, 1996)

Besides the impact on the quality of life, lost work time, falls is the most costly occupational hazard in many countries (Gavious et al. , 2009). Courtney (2001) concluded that annual cost caused by fall accident drop to six billion dollar in the US and total of maintenance cost from fall accidents drop to eleven billion dollar in 2004 (Meerding, 2005).

Statistic based on the number of fall accident and the impact caused, an effort to prevent fall accident is an important priority in increasing the occupational safety level in construction industry (Chie, 2004; Bentley, 2006; Lehtola, 2008). Knowledge about factor causing fall accident and a comprehensive understanding various of circumstances is relevant to understand the factors contributing to construction fall accident and translating that understanding into recommendations for fall prevention (Martin, 2009; Hsiao and Simeonova, 2001).

David Hume in Nugraheni (2008) concluded that causality concept of factors causing the accidents is multi factors and complex. A workplace accident can be caused by a single factor or several factors that interact and contribute (Abdelhamid and Everett, 2000). Many studies have been conducted to measure different factors contributing to the risk of falls, different information sources, different methods approaches and tools application. Hu (2011) has structured the factors contributing to fall by reviewing 563 articles about the fall in the last 10 years in some countries. Unfortunately, yet there are few studied empirically examines the interactions and causal relationship between the causes vulnerability leading to fall accidents . In order to explain accident causality, this study provides a greater understanding of the interaction between the cause vulnerability leading to fall accidents.

2. Fall Accident Causation

An Accident can be defined as something that is unplanned, uncontrollable, and unwanted, which disrupt the formal functions of a person or persons and causes injury or near miss (Hinze, 1997) or an unplanned, uncontrollable events that can cause or generate injuries on workers, damage on equipments and other loss (Rowlinson, 2003).

An Accident in construction project resulting in physical injuries and fatalities can be broadly categorized into the following eight basic groups (Hinze, 2005; Haslam et al 2005 in Imriyas (2009): (i) falling from height, (ii) Struct by falling object/ moving vehicles, (iii) excavation-related accidents, (iv) operations of machinery/ tools related accidents, (v) electrocutions, (vi) fire/ explosion, (vii) failure of temporary structure, and (viii) others.

An accident fall is defined as an event in which a person coming to rest unintentionally on the ground or other lower level, not by the result of a major intrinsic event such as (stroke) or overwhelming hazard (Tinetti, 1988 in Joylene, 2009)

Fall accident consists of 2 types, which are (i) falling from height, for example: fall from groundwork, fall from ladder, slipped from ladder. (ii) fall from elevation, for example, falling by slipping, tripped, or fall to the ground or floor/lower level (Joylene, 2009). Hinze (2002) the kinds of fall accident on building is categorized by its type, that is: i) fall from elevation, ii) fall from platform, iii) fall from ladder, iv) fall from piled matter, fall from stairs, v) fall into openings, vi) fall from roof, vii) fall to lower level. According to a record by PT. Jamsostek (2007-2010), fall accidents on building projects in Indonesia are (i) fall from scaffolding, (ii) fall from ladder, and (iii) fall from structure. The type of work that dominates the cause of a worker to get an accident is scaffolding installation work and finishing work (Latief, 2011). Knowledge regarding extrinsic and intrinsic factors toward fall accident highly contributes to occupational safety planning for the workers. (Gauchard, G., 2001). Bentle (2009) concludes the factors causing occupational work was influenced by extrinsic factors or latent factors, which consist of design factors, organization factors, and environmental factors. Moreover, the Bentle's model was used by Ware (2009), which using research in Nasa Construction Industry, which concluded that the factors causing fall accident are multifactor and extremely complex. Significant factors that cause the risk to fall are Task Related Factor, Human/Personal Factor, Environment Factors and organizational factors.

Personal factor or human factor is more dominant in causing fall accidents if compared to non-personal factor including equipment factor, organization factor, and management factor (Latief, 2011). Arifuddin (2012) conclude the vulnerability of construction in process leading to fall is caused by five factors including human factors, equipment factors, organization factors, management factors and environment factors.

(1) Human factor are aspects that can be observed through some of the conditions from human behaviors that can trigger the vulnerability causes of fall accidents such as lack of awareness of the use of PPE and methods (Hu, 2011; Joylene 2009; Tam, 2004; Suraji, 2001), poor safety conscientiousness of workers (Tam, 2004, Toole, 2002) , low education level of workers (Zou and Zhang, 2009; Tam, 2004), lack the experience of workers (Hu, 2011; Joylene 2009; Aksorn and Hadikusumo, 2007), Excessive overtime work for labor (Higa and Kim, 2013; David 1983) and lack of health and physical characteristics of workers (Hu, 2011)

(2) Equipment factor includes a vulnerable condition such as lack of safety equipment specifications (Zou and Zhang, 2009; Tam, 2004; Toole, 2002; Suraji, 2001;), lack of inspection and maintenance on equipment (Zou and Zhang, 2009; Tam 2004) and no permit operation of the equipment (Zou and Zhang, 2009; Tam 2004).

(3) Organization factors are factors that describe the conditions that led to a vulnerability to the accident falls such as lack of organizational commitment (Zou and Zhang, 2009; Tam, 2004) and lack of strict regulatory penalties and no/low reward (Aksorn and Hadikusumo, 2007).

(4) Management factors are factors that describe the conditions that led to a vulnerability to the accident falls such as low/no safety program and standard (Zou and Zhang, 2009; Tam, 2004), Low/no safety training and education (Zou and Zhang, 2009; Toole, 2002; Tam, 2004), lack of strict operational procedures and planning (Suraji, 2001; Tam; 2004; Toole, 2002), poor standards of safety contracts (Zou and Zhang, 2009), less / no supervision and monitoring safety (Zou and Zhang, 2009), less / no budget safety (Atkinson, 1998) and less / no safety communication (Tam, 2004).

(5) Environment factor are factors that describe the conditions that led to a vulnerability to the accident falls such as poor working surfaces and platforms (Hu, 2011; Joylene 2009; Tideikssar, R., 1996), lack of lighting systems (Joylene 2009; Zou and Zhang, 2009; Atkinson, 1998;); and severe weather (Zou and Zhang, 2009; Atkinson, 1998).

3. Vulnerability of Construction Project

The Building project is one of the construction project in the construction process is a complex process and requires coordination from various types of skill and technology; a difficult situation, a complex activity, and most of its activities are carried out in altitude. Therefore, this will lead to the vulnerability of building construction toward accidents (Asiyanto, 2005). Work-related falls from heights remain a significant problem for workers in industry. An occupational accident event is always preceded by preceding events that urge the event to happen, that causes a system to be vulnerable toward occupational work. The term "vulnerability" is used to explain the system characteristic where vulnerability shows how far the project vulnerable toward bad influence from a change (Fidan, 2008; Brooks, 2003). Project vulnerability already exists before risk event, but vulnerability will not be significant until the risk event happens (Zhang, 2007).

According to Ezell (2007) in Fidan (2008), the understanding of risk and the understanding of vulnerability are often confusing and they are often considered as the same thing. According Fidan (2007), vulnerability is very much depended on the endurance that shows the ability to receive or reject expected change. Meanwhile, the risk is impact/loss emerged and this risk is depended on the three elements, they are danger, vulnerability, and exposure (Chrichton, 1999). According to Agarwal and Blockey (2007), risk is the result of combination of danger and vulnerability.

Reducing vulnerability is one important method in managing risk, but reducing risk impact is not related with reducing system's vulnerability. Risk response strategy that developed through an approach based on risk will be enough to cover the cost of extreme event, although the success of this application is not depended on vulnerability reduction (Agarwal and Blockery, 2007).

Turner (2003) in Fidan (2008) has described the relation between the root of the problem, vulnerability, danger and disaster in a construction project. Presure-And-Release/ PAR Model describes that, a disaster happens due to the appearance of danger. This danger is heavily triggered by vulnerability condition, which appear due to the existence of root of the problem that later will evoke pressure and cause unsafe conditions. In addition, if the vulnerability condition is combined with danger, then a disaster will happen and cause risk/loss (Turner et al, 2003).

4. A Confirmatory Factors Analysis (CFA)

After Confirmatory Factors Analysis (CFA) is one kind of Factors Analysis Method (FAM).
According to Joreskog and Sorborn (1993), CFA analysis is used to test uni-dimensional, validity, and reliability of construct measurement model that cannot be directly measured.
The purpose of CFA analysis is to confirm or to test a model namely the measurement model, where the measurement comes from a theory. CFA analysis study is focusing in two matters; they are (Hair, 2006):
(i) Measuring accuracy and consistency of indicators that are conceptualized as uni-dimensional;
(ii) Determining indicators that are dominantly shape the studied construct.
Several testing index to identify the proposed model have met the criteria requirements of a good measurement model of structural equation, like: (Hair et al; 1998):
1. *Degree of Freedom (df)* must be positive
2. χ^2 (*Chi-Square*) and probability are a fundamental testing tools to measure overall fit, that is likelihood ratio of Chi Square statistic. If a model is considered good, then it must have Chi Square = 0, which means no difference. The recommended significant level of receiving is if $p \geq 0.05$.
3. *CMIN/DF* (Normed Chi Square) or CMIN/DF is a measurement obtained from Chi Square divided by Degree of Freedom. The recommended value to achieve agreement of a model is *CMIN/DF* value ≤ 2.0 or 3.0.
4. *Goodness of fit Index (GFI)* is used to reflect the level of overall model agreement that calculated from model of quadratic residue predicted by comparing it with the actual data. Goodness of Fit Index value is normally range from 0 to 1. The larger the number of research's sample, the larger the value of GFI. When a better score is closer to 1, it indicates that the tested model has better agreement. A good GFI value is ≥ 0.90.
5. *Adjusted GFI (AGFI)* stated that GFI is an analog of R^2 *(R square)* in multiple regression. The recommended acceptance level is when the value ≥ 0.9.
6. *Tuker-Lewis Index (TLI)* is an alternative of *Incremental Fit Index* that compares a tested model against a baseline model. The recommended value to be accepted is ≥ 0.9. If a value is closer to 1, it indicates that the value is a *very good fit*.
7. *CFI (Comparative Fit Index)* is known as *Bentler Comparative Index. CFI* is an incremental agreement index that also compares the tested model with null model. This index is considerably good in measuring the agreement of a model because it is not affected by the size of the sample
8. *RMSEA (Root Mean Square Error of Approximation)*. *RMSEA* is a measuring index, which is not affected by the size of the sample, therefore it is common to use this index to measure fit model in a large number of samples. *RMSEA* indicates goodness of fit, which is expected if the model is estimated within a population. *RMSEA* value ≤ 0.08 is the index of which it can be accepted as the model.
Therefore, based on the above discussion, the criteria can be summarized as follows:

Table 1. Indeks Goodness of Fit

Good of Fit Index	Cut off Value
Chi Square	Expected to be small
Significance Probability	≥ 0.05
RMSEA	≤ 0.08
GFI	≥ 0.90
AGFI	≥ 0.90
CMIN/DF	≥ 0.90
TLI	≥ 0.90
CFI	≥ 0.95

5. The Conceptual Model

The conceptual framework of this study was to test the conceptual model with the model empirical. Conceptual model was developed based on a literature review of theories and models of accident causation. The model describes the structure of the causal relationship of factors that cause vulnerability leading to fall accidents in high-rise building construction project. Concerning with vulnerability of construction project to fall accident, it is assumed that such fall accidents occur triggered by conditions of vulnerability in which the conditions of this vulnerability can be viewed from five aspects include human factors, equipment factors, organizational factors ad management factors. An

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illustration of the main factors of vulnerability leading to fall accidents can be seen in Fig. 1.

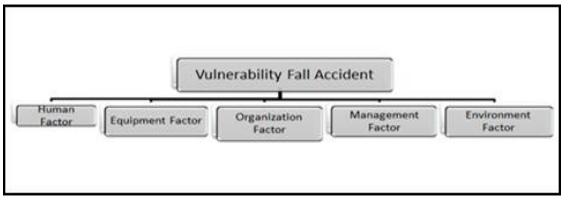

Figure 1. Conceptual Model

In this research, system's vulnerability is an endogenous variable while the other five variables are exogenous variable. The hypothetical model proposed based on literature review and deductive analysis of the factors that are commonly causing occupational accident, which is explained on the figure.

Model tested using data and information obtained in the form of perception that is constructed from respondent's knowledge and experience. Data collection instrument is questionnaire survey that involved 100 respondents as the information sources. The respondents are the parties (stakeholders) who are directly involved in construction project with > 5 years work experience in building construction project; they consists of safety officers, supervisors, and the labor who are randomly appointed and distributed in 30 building construction projects in Jakarta and its surrounding area.

The respondents were asked to choose answers, which already prepared in the questionnaire, according to their own perception. The perception is built from the knowledge and the experience of the respondents regarding contribution level of each factor toward the vulnerability of construction project toward fall accidents. The answers were given in graded choice (Likert scale 1-5), starting from not at all, not enough, enough, more than enough, very much. Score 1 means no contribution, while score 5 means giving a lot of contribution toward vulnerability of building construction project toward fall accident.

Data processing is using Confirmatory Factors Analysis (CFA) method. CFA Analysis is used to test hypothesis structure that has been conceptualized. The data adequacy as a learning process has also been fulfilled; with the total of (N) data is as much as 100 and the processed data ⩾ 100 data. Data processing is carried out using Lisrel 8.54 software (Joreskog & Sorbom, 2003).

6. Finding and Discussion

From the results of data processing, as shown in Table 2, a validity test at a significance
level is obtained on all factors. except the The result of the reliability test obtained by Cronbach's Alpha is 0.713 and it is greater than the Alpha table which is 0.279. Thus it can be said that the research data is valid and reliable enough to be used for further processing stages.

Table 2. Data Testing Result

Parameter	Value	Criteria
Chi square	2.78	Good Fit
DF	6	Good Fit
P-Value	0.83644	Good Fit
RMSEA	0.000	Good Fit
GFI	0.99	Good Fit
AGFI	0.97	Good Fit
CMIN/DF	0.463	Marginal Fit
TLI	1.50	Good Fit
CFI	1	Good Fit

The complete result of empiric model of the vulnerability factors measurement model against fall (FVi) can be seen on Figure 2.

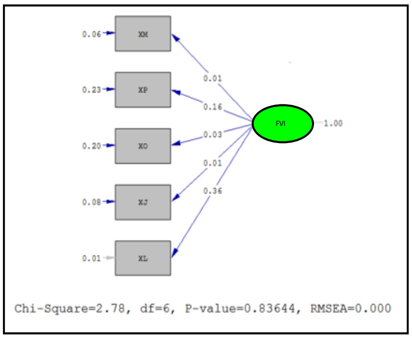

Figure 2. Measurement Model of Factors of Construction Project Vulnerability

Based on the above analysis result, we can discuss the following Chi Square value as much as 2.78 with *P-Value* = 0.83644 (≥ 0.05), df = 6 (positive), RMSEA value = 0.000 (≤ 0.08). The GFI value = 0.99 (≥ 0.90) and according to Wijayanto (2008), when GFI value approaching 1, Results have shown that the conceptual model is good fit good with empirical models derived from data processing. It indicates that factors causing vulnerability leading to fall consists of human factors (Higa and Kim, 2013; Hu, 2011; Zou and Zhang, 2009; Joylene 2009; Aksorn and Hadikusumo, 2007; Tam, 2004; Toole, 2002; Suraji, 2001; David 1983), equipment factors (Zou and Zhang, 2009; Joylene 2009; Tam, 2004; Toole, 2002; Suraji, 2001), organization factors (Zou and Zhang, 2009; Joylene 2009; Aksorn and Hadikusumo, 2007; Tam, 2004), management factors (Zou and Zhang, 2009; Tam, 2004; Toole, 2002; Suraji, 2001; Atkinson, 1998) and environment factors (Hu, 2011; Zou and Zhang, 2009; Joylene 2009; Tam, 2004; Toole, 2002; Tideikssar, R., 1996)

Based on loading factor (λ) each five factors were analyzed with CFA has shown results that loading factor of environment factors (λXl) = 0.36; equipment factors (λXp) = 0,16; organization factors (λXo) = 0,03; management factors ((λXj) = 0,01 and human factors ((λXm) = 0,01.

According to these result, environment factors was the most significant factors in measuring vulnerability level toward fall was environment factor (λ = 0,36> 0,30 (Wijayanto, 2008). Environment factors are aspects that can be observed through some of the conditions from human behaviors that can trigger the vulnerability causes of fall accidents such as poor working surfaces and platforms (Hu, 2011; Joylene 2009; Tideikssar, R., 1996), lack of lighting systems (Joylene 2009; Zou and Zhang, 2009; Atkinson, 1998;); and severe weather (Zou and Zhang, 2009; Atkinson, 1998).

The equipment factors was marginal significant factors (λ) = 0,16 as a vulnerability causes lead to accidental falls. *Equipment factor* includes lack of safety equipment specifications (Zou and Zhang, 2009; Tam, 2004; Toole, 2002; Suraji, 2001;), lack of inspection and maintenance on equipment (Zou and Zhang, 2009; Tam 2004) and no permit operation of the equipment (Zou and Zhang, 2009; Tam 2004).

7. Conclusion Remark

Based on the analysis and discussion, it can be concluded as follows:

1. From the final modeling results, it is vulnerability of construction in process leading to fall is caused by five factors including human factors, equipment factors, organization factors, management factors and environment.
2. Vurnerability of construction project in process leading to fall Environment factor is the most significant factor to the measurement of vulnerability leading to fall
3. *CFA* analysis result showed that Empirical Model of the factors causing the project vulnerability toward fall is considered a good fit with the conceptual model developed in the beginning.

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