Analysis Of Relation Between Risk-Based Work Breakdown Structure (WBS) On Integrated Design And Construction Works Of Design And Build Contract On Mechanical And Electrical Works Of High Rise Building For Improving Safety Performance

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Abstract.

The construction industry has had the highest accident rate worldwide for decades. Identifying risks as early as feasible during the pre-construction or design phase is essential to preventing construction accidents. To generate a structured list of risks, a Work Breakdown Structure (WBS) is used to identify risks. Although numerous studies have proposed using Work Breakdown Structure (WBS) to identify risks, no one has analyzed the relationship between Work Breakdown Structure (WBS) and risk to reduce construction accidents. Consequently, this study aimed to investigate the impact of Work Breakdown Structure (WBS) risk during the design and construction phases on construction safety performance. The analysis of relationships will be conducted using statistical methodologies. The study's findings will demonstrate that Work Breakdown Structure (WBS) risk affects construction safety performance.

Keywords: *Risk, work breakdown structure, mechanical and electrical, and construction safety performance*

I. INTRODUCTION

Construction is a risky sector of the economy where fatal and non-fatal work accidents are frequent [1]. Construction has a five-fold higher death rate than the manufacturing sector, while the likelihood of serious injury is 2.5 times higher [2]. Accidents on the construction site can hinder project progress, raise expenses, and impair the contractor's reputation [3]. High-rise buildings are one of the construction sectors with the highest rate of accidents [4]. Numerous workers constructing high-rise buildings suffer yearly injuries, fatalities, and financial losses [5]. Interior, mechanical, electrical, and pipe work is one of the high-rise building work categories that generate more issues than other construction activities [6]. The installation and use of intricate mechanical, electrical, and plumbing systems, as well as the installation of cables, mechanical equipment, and pipelines, are all included in mechanical and electrical work. The possibility of human mistakes, such as incorrect installation and exposed connections, is increased with complexity. The success of accident prevention largely depends on knowledge of the causes of accidents, so it is vital to ascertain the causes for reducing the hazard to prevent construction accidents [7]. Previous research has shown that architects, designers, and structural engineers have a role in building accidents in addition to contractors [8] [9].

In connection with this, the Department of Occupational Safety and Health (DOSH) has identified the factors contributing to construction accidents that start before work begins [10]. As an illustration, 44% of construction-related fatalities in Australia are related to design [11]. A survey of 184 professionals in the UK revealed that complex designs were likely to affect construction accidents [12]. The Work Breakdown Structure (WBS) is another strategy for reducing the risk of accidents during construction and concentrating on the design phase [13]. Using a Work Breakdown Structure (WBS) facilitates the division of labor into smaller, quantifiable tasks, making it simpler to identify the risks attached to each activity [14]. A risk based WBS also makes it possible to identify the riskiest job categories [15]. Several studies have suggested using WBS to determine the risks of building accidents in this setting. However, there is no analysis of the relationship between risk, WBS, and construction safety performance. Considering this, this study aims to clarify how hazards identified by the WBS relate to construction safety performance.

II. METHODS

This research is included in the quantitative research with data collection methods using interviews with five experts who have expertise in the mechanical and electrical fields of high-rise buildings with more than ten years of experience and a minimum of bachelor's degree education and distributing questionnaires to respondents who have expertise in the mechanical and electrical fields of buildings high-rise with more than five years of experience and a minimum of of bachelor's degree education. After the questionnaires were collected, correlation tests, factor analysis, and regression were carried out on the data obtained using SPSS 25 software. Several model tests were carried out from the regression model obtained: the F test, t-test, and autocorrelation test.

III. RESULT AND DISCUSSION

1. Correlation analysis

Correlation analysis determines the relationship of the independent variable, namely the risk of WBs, to the Y variable, namely construction safety performance. To measure the strength of the relationship between these variables, the correlation coefficient is used to show the characteristics of the relationship and its meaning in the form of a positive or negative relationship. If the relationship is correlated, it is marked with an asterisk (** or *). The results of the correlation test can be seen in Table 1.

Table 1. Correlation test results

Variable	Hazard	Risk	Correlation Coefficient	Sig. (2-tailed)
X2.2	Unclear scope of work	Error in completely defining project activities	.352*	0.044
X2.5	Lack of experience and competence of the survey team	Location measurement and mapping errors	.397*	0.018
X2.6	The selected survey equipment is not calibrated	The survey data results are not accurate	.433*	0.010
X2.15	The estimated cost is too minimum	There is a system that can not be implemented	.336*	0.045
X2.20	Error in calculating the volume	There is a system that can not be implemented	.412*	0.014
X2.24	Lack of coordination with structural and architectural experts	Design collisions on structural and architectural elements	.377*	0.025
X2.55	Crushed by falling material while moving	Wounds	.377*	0.029
X2.90	A sharp object hits the cable	The cables are chipped and damaged	.360*	0.034
X2.195	Stuck workers	Fracture	.394*	0.020
X2.243	Inhaling welding fumes	Respiratory tract infection (ARI)	.364*	0.037
X2.276	Worker fell	Fracture	.554**	0.002
X2.355	Touching exposed work equipment wires	Convulsions	.413*	0.016

2. Factor analysis

The main principle of conducting factor analysis is looking at the Kaiser-olkin Measure (KMO) and significance values (sig.) The requirements for factor analysis are KMO values > 0.5 and sig. < 0.5. The results of the KMO & Bartlett's test in this study can be seen in the Table 2.

Table 2. KMO & Bartlett's test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.721
Bartlett's Test of Sphericity	Approx. Chi-Square	244.454
	df	66
	Sig.	0.000

It can be seen in the table above that the KMO value is > 0.5 and the sig. < 0.5, this means that the factor analysis process can be continued. Furthermore, the results of the factor analysis test produce the value of the rotated component matrix shown in Table 3.

Table 3. Rotated component matrix

	Component		
	1	**2**	**3**
X2.2	0.309	0.007	0.790
X2.5	0.145	0.928	-0.020
X2.6	0.183	0.891	-0.115
X2.15	0.476	0.656	0.033
X2.20	0.109	0.751	0.329
X2.24	0.081	0.767	0.389
X2.55	0.753	0.196	0.109
X2.90	0.868	0.144	0.138
X2.195	0.850	0.091	0.170
X2.243	0.134	0.191	0.908
X2.276	0.764	0.349	0.262
X2.355	0.819	0.074	0.091

The table above shows the factor loading of each data entry. Eight columns are formed, meaning the SPSS program forms three components or dimensions. Then eight new dimensions are obtained, namely factor 1 (X2.55, X2.90, X2.195, X2.276, X2.355), factor 2 (X2.5, X2.6, X2.15, X2.20, X2 .24), and a factor of 3 (X2.2 and X2.243). The naming description of the three components can be seen in Table 4.

Table 4. Grouping based on factor analysis

Faktor 1		
Variabel	**Bahaya**	**Risiko**
X2.55	Crushed by falling material while moving	Wounds
X2.90	A sharp object hits the cable	The cables are chipped and damaged
X2.195	Stuck workers	Fracture
X2.276	Worker fell	Fracture
X2.355	Touching exposed work equipment wires	Convulsions
Faktor 2		
Variabel	**Bahaya**	**Risiko**
X2.5	Lack of experience and competence of the survey team	Location measurement and mapping errors
X2.6	The selected survey equipment is not calibrated	The survey data results are not accurate
X2.15	The estimated cost is too minimum	There is a system that can not be implemented
X2.20	Error in calculating the volume	There is a system that can not be implemented
X2.24	Lack of coordination with structural and architectural experts	Design collisions on structural and architectural elements
Faktor 3		
Variabel	**Bahaya**	**Risiko**
X2.2	Unclear scope of work	Error in completely defining project activities
X2.243	Inhaling welding fumes	Respiratory tract infection (ARI)

These three components will be further processed in regression analysis to find a linear regression equation model.

3. Regression analysis

Regression analysis was carried out to determine how much influence the independent variable (x) has on the dependent variable (Y). Regression analysis in this study uses input variables from the factor analysis results. The results of the regression analysis with the help of SPSS can be seen in Table 5.

Table 5. Model summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.601[a]	0.362	0.335	0.591	
2	.785[b]	0.617	0.583	0.468	
3	.825[c]	0.681	0.637	0.436	2.031

a. Predictors: (Constant), REGR factor score 1 for analysis 1

b. Predictors: (Constant), REGR factor score 1 for analysis 1, REGR factor score 2 for analysis 1

c. Predictors: (Constant), REGR factor score 1 for analysis 1, REGR factor score 2 for analysis 1, REGR factor score 3 for analysis 1

d. Dependent Variable: Y1.1

The table above illustrates the level of confidence in the model and the number of models that may be modified. The adjusted R2 value indicates the confidence level of the model obtained. The adjusted R2 value obtained is 0.637 or 63.7%. Construction safety performance can be explained by factors 1, 2, and 3. The following are the results of the ANOVA from the regression analysis shown in Table 6.

Table 6. Anova results

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4.743	1	4.743	13.597	.001[b]
	Residual	8.372	24	0.349		
	Total	13.115	25			
2	Regression	8.088	2	4.044	18.500	.000[c]
	Residual	5.028	23	0.219		
	Total	13.115	25			
3	Regression	8.926	3	2.975	15.623	.000[d]
	Residual	4.190	22	0.190		
	Total	13.115	25			

a. Dependent Variable: Y1.1

b. Predictors: (Constant), REGR factor score 1 for analysis 1

c. Predictors: (Constant), REGR factor score 1 for analysis 1, REGR factor score 2 for analysis

d. Predictors: (Constant), REGR factor score 1 for analysis 1, REGR factor score 2 for analysis 1, REGR factor score 3 for analysis 1

The table above shows the significant value of the effect of all independent variables (X) on the dependent variable (Y). From the output, it can be seen that the significance value is <0.05, meaning that the three factors become inputs in the regression analysis, which significantly affect construction safety performance. The following is a table of coefficient values from the results of the regression analysis shown in Table 7.

Table 7. Coefficient value

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.302	0.116		19.817	0.000
	REGR factor score 1 for analysis 1	0.470	0.127	0.601	3.687	0.001
2	(Constant)	2.315	0.092		25.156	0.000
	REGR factor score 1 for analysis 1	0.484	0.101	0.620	4.800	0.000
	REGR factor score 2 for analysis 1	0.343	0.088	0.505	3.912	0.001
3	(Constant)	2.327	0.086		27.031	0.000
	REGR factor score 1 for analysis 1	0.487	0.094	0.623	5.169	0.000
	REGR factor score 2 for analysis 1	0.345	0.082	0.508	4.211	0.000
	REGR factor score 3 for analysis 1	0.180	0.086	0.253	2.098	0.048

The table above contains each X factor's constant and coefficient values. Based on these outputs, a linear regression equation can be made as follows:

Y = 2.327 + 0.4887 (Factor 1) + 0.345 (Factor 2) + 0.180 (Factor 3)

4. F test

The F test was conducted to determine whether the previous regression model was right or wrong, so a hypothesis test was needed. If F research > F table, then H0 is rejected, H1 is accepted, and vice versa. The F table in this study is 3.42, and the hypothesis in this study is as follows:

H0: There is no relationship between the risk of integrated design and construction work in engineering and construction contracts in the mechanical and electrical work of high-rise buildings on construction safety performance.

H1: There is a risk relationship between the design and construction work of integrated engineering and construction contracts in the mechanical and electrical work of high-rise buildings on construction safety performance.

The research results found that the research F value was 15,623, then H0 was rejected, and H1 was accepted. This means there is a risk relationship between the integrated design and construction work of engineering and construction contracts in high-rise buildings' mechanical and electrical work on construction safety performance.

5. T test

The t-test was conducted to see the influence of factor 1, factor 2, and factor 3 on construction safety performance. If t research > F table, then H0 is rejected, H1 is accepted, and vice versa. The t table in this study is 2,064. The study results found that the t value of factor 1 was 5,169, factor 2 was 4,211, factor 3 was 2,098, then H0 was rejected, and H1 was accepted. This means that there is a relationship between factor 1, factor 2, and factor 3 on construction safety performance.

6. Durbin Watson test

Durbun Watson test is done to determine whether there is a deviation from the classical autocorrelation assumption. The provisions are as follows:

- If d < dL or d > 4-dL then the null hypothesis is rejected = autocorrelation
- If dU < d < (4-dU), then the null hypothesis is accepted = no autocorrelation
- If dL < d < dU or (4-dU) < d < (4-dL) = no definite conclusion will be drawn.

From the output results in table x, the value of Durbin Watson is 2,031. Meanwhile, the Durbin Watson values in the table are dl = 1.1431 and du = 1.6523. Because, in this case, the DW value is in the area between dU and (4-dU) where 1.6523 < 2.031 < 2.3477, it is concluded that there is no autocorrelation.

IV. CONCLUSION

This study shows that there is a significant relationship between the risks identified through the WBS of the Integrated Design and Development Stage of the Design and Build Contract on mechanical-electrical work on construction safety performance. Applying the WBS can better identify and control the risks connected to electrical and mechanical work. Construction safety performance can be greatly improved by having a thorough awareness of the dangers connected to mechanical and electrical work, especially when WBS is used correctly. It is possible to assess risks effectively and implement the necessary controls to reduce the likelihood of accidents by thoroughly identifying them.

Integrating risk analysis into the WBS Stage of Integrated Design and Development of Design and Build Contracts is crucial for enhancing construction safety performance in mechanical and electrical work. The execution of suitable countermeasures will be encouraged by this stage, which will aid in early risk identification, efficient coordination between the various parties involved, and facilitation of risk identification. This finding highlights the significance of focusing on the correlation between WBS risk at the design and construction phases of integrated design and build contracts and construction safety performance in mechanical-electrical work. The proper risk identification and application of efficient risk control methods in the WBS at the appropriate phases must be carefully considered to increase construction safety.

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