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Original Article

Investigating the Relationship between Risk Factors and Construction Safety Performance in Design-Build Projects of High-Rise Building

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Abstract *- High-rise building projects globally experience an alarming accident rate of up to 45% and are primarily influenced by the working environment and behavior. Identifying risk is essential to prevent accidents proactively and needs to be in the project planning phase. Work Breakdown Structure (WBS) is seen as a tool to help identify risk from work packages, and several research have suggested generating risk from each activity to reduce accidents. Presently, no research has been conducted on the relationship between risk and construction safety performance indicators. Therefore, this research aimed to evaluate the risk identification process based on all activities in WBS, including preparation, design, and construction phases, to integrate a whole design and build contract approach not previously explored. It also investigated the relationship and impact of risk during the design and construction phases towards indicators of construction safety performance. Statistical methodology was conducted to analyze the relationship, which resulted in a linear equation model with a strong relationship between risk and safety performance. The result showed that risk-based WBS affects the overall construction safety performance of architectural and exterior works construction on high-rise buildings.*

Keywords *- Architecture work, Construction safety performance, Risk, Work Breakdown Structure.*

1. Introduction

The construction industry is presently one of the most unsafe industries [1]. This is because the risk of fatal injury is two and a half times higher than manufacturing industries and five times higher in mortality rate [2]. In 2019, the Department of Occupational Safety and Health (DOSH) Malaysia stated that 7,984 construction accidents occurred annually [3]. By November 2022, 265.334 construction accident cases were recorded in Indonesia [4], with more than 45% of accidents caused by a lack of work standards. High-rise building projects such as residential, commercial, and industrial buildings have an accident rate of 45%, which is influenced by the working environment and worker behavior [5]. Workers, as direct stakeholders on-site, directly participate in the unstructured environment of construction projects due to its inherent complexity and difficulty [1]. According to preliminary studies, 85% and 15% of accidents in construction are caused by unsafe acts and conditions [6, 7].Installation of architectural parts in high-rise building projects causes issues and safety accidents because design schemes often decide construction methods and schedules [7]. Complex designs are likely to impact construction accidents [8]. [9] stated that 44% of construction accidents in Australia were associated with complex design. The construction phase of architectural works includes about 258 highly technical tasks related to strict construction drawings [10]. These tasks comprise specific behavior of workers, materials, structures, equipment, tools, and work environment, which directly affect construction safety [1]. One example of a fatal accident that occurred while installing architectural components for tall buildings was a fall from height, thereby leading to disability and even death [11]. Therefore, the more difficult and complex the design of the building, the higher the possibility of human error that causes accidents.The methods, equipment, and architecture materials are derived from tasks or activities in the Work Breakdown Structure (WBS). As the basis of most construction projects, WBS is a form of hierarchy and decomposition of work inside a project scope.

It is essentially considered by all team members to carry out project objectives and the outcome requirements known as deliverables [12]. Deliverables are measurable, verifiable, and tangible results of a project [13]. According to Su and Lei [14], WBS is a planning tool which contains detailed instructions for completing the project. It is also a determinant of work mileposts and project status reports and is used to prevent project deliverables from being neglected. This tool is also used to help identify and analyze the risk of the project [15].

Mitigation and prevention of accident rates in the construction sector need to be appropriately done by companies through the enforcement of safety measures and management systems to reduce the number of accident cases [3, 16]. Furthermore, designers are liable to ensure construction safety by consistently considering it in design from the conceptual or planning phase. The planning and design phases allow taking away risks earlier than they arise on the site, and the capability to eliminate these risks decreases as the project progresses [17]. The design process can create unsafe conditions in construction. Therefore, hazard identification and prevention must be assisted earlier than the construction phase to avoid safety challenges [18]. To accomplish safety objectives, contractors, designers, and architects need to identify and manage hazards during project design phases to eliminate risk in the construction phase.

Design-build contract is a design procurement and construction system handled by a single person. It has the advantage of increasing infrastructure development because it can start the construction process before the detailed implementation drawings are completed. This helps to increase the project completion time, which is very risky for scope changes because it is ambiguous and increases the level of project complexity. The higher the complexity of the project, the greater the risk of accidents due to the many deficiencies in the planning and design process.

Risk management is important in the construction process. It needs to be implemented in a structured manner, specifically in terms of scope, time, cost, quality, and human resources in the early phase of a project or planning stages. WBS is one of the ways to prevent risk and accidents prepared by identifying potential risks from each task or activity. The hazard of every work package in WBS is used to obtain the global vision of the project [19].

WBS is a planning method used to improve project performance, which leads to less rework, high-quality output, and enhanced site control in construction projects [20].The process is obtained by capturing the riskiest activities for architectural work. Several studies recommend the use of WBS to determine the risk of construction accidents with the consideration of a proper and efficient risk control method.

This shows the need for safety planning from the initial stage. Several preliminary research focused on the relationship between construction risk and work safety in conventional contracts to improve time, cost, and quality performance. In WBS research conducted in recent years, the main focus was developing safety plans based on WBS standards and risk management results.

Therefore, the influence of risk on safety performance remains unknown. There is also limited research on the quantitative relationship analysis between risk of construction accidents, WBS, and safety performance. Therefore, this research analyzed how hazards identified from the activities in WBS will predispose three measurement indicators of construction safety performance and clarify the degree of relationship.

This is to ensure preventive actions are arranged in accordance with the negative impact risk has on quantitative project success. The model produced in this research will make it possible to measure objectively and measurably how much safety performance needs to be improved in the lifecycle of the project.

2. Materials and Methods

The methods used in this research were a literature review, questionnaire surveys, and expert interviews. Literature review was conducted to identify the list of hazards and risks of architecture work from WBS of high-rise buildings. The list was further validated by 5 experts in architectural and exterior construction for high-rise buildings with a minimum of bachelor's degrees and more than ten years of experience.

The risk list was processed into a questionnaire of 382, and 3 independent and dependent risk variables were selected from construction safety performance indicators. The questionnaire was then distributed to 30 respondents engaged in the construction sector to provide risk scores and measure the relationship between risk and construction safety indicators as quantitative data.

The construction safety performance indicators are resources (Y1), schedules (Y2), and forms of monitoring (Y3). The respondent should have 5 years plus experience with a bachelor's degree as minimum educational level; after completing the questionnaires, homogeneity and data adequacy tests were carried out before proceeding with correlation test, factor analysis, and regression test using SPSS 26 software. The linear equation model obtained from regression analysis was tested using F-test, T-test, and Durbin Watson. The result is an equation model that shows and explains the relationship between risk factors in architectural work and construction safety performance.

Table 1. Correlation test analysis result

Variables		Hazard Condition	Description of Risk	Level	Correlation Coefficients	Sig. (2-tailed)
Y	X					
Y1	X’6	Primary data and literature are outdated.	The output of the site design does not comply with the corresponding regulatory requirements.	Medium	-.427*	0.019
	X’9	Incomplete data collection	Error in calculating design and building area.	Medium	-.370*	0.044
	X’21	Weather primary data and literature are incomplete.	Error in site design and building mass.	Medium	-.467**	0.009
	X’82	Workers perform activities that are not in accordance with body ergonomics and beyond their abilities.	Muscle sprain	Low	-.376*	0.041
Y2	X’1	Lack of experience and competence of the survey team.	Delays in work processes and reports preparation.	Medium	-.427*	0.019
	X’2	Lack of planning and preparation by the team.	Delays in work processes and reports preparation.	Medium	-.516**	0.004
	X’5	Experts are not careful in choosing the appropriate survey tool.	Inaccurate field survey data	Medium	-.415*	0.022
	X’6	Primary data and literature are not updated.	The output of the site design does not comply with the corresponding regulatory requirements.	Medium	-.427*	0.019
	X’20	Survey equipment is not calibrated and falls when used.	Field measurement data is not accurate.	Medium	-.384*	0.036
	X’21	Weather primary data and literature are incomplete.	Error in site design and building mass.	Medium	-.562**	0.001
	X’29	Very short planning time.	Design output is inaccurate.	Medium	-.530**	0.003
	X’38	Building master plan is not in accordance with the Regional Spatial Plan (RTRW) and Detailed Spatial Plan (RDTR).	PBG application rejected.	High	-.538**	0.006
	X’40	Experts lack experience in applying design for safety elements in design.	Design does not consider construction safety aspects.	Medium	-.384*	0.036
	X’45	Field survey data is incomplete.	Drawings and methods of work are inaccurate.	Medium	-.364*	0.048
	X’47	Data sources and literature on unit cost of work in management have not been updated.	Reduced building dimensions and building failure.	High	-.427*	0.033
	X’94	Tool-washing sludge and paint residue are disposed of carelessly.	Land and water pollution	Medium	-.398*	0.029
	X’96	Worker's hand hit by a hammer during thread installation.	Muscle sprain	Low	-.375*	0.041
	X’128	Worker falls from height.	Mortality	High	-.427*	0.033
	X’129	Worker crushed by aluminium frame.	Mortality	High	-.447*	0.025
	X’153	Worker crushed by aluminium frame.	Mortality	Medium	-.463**	0.010
	X’171	Facing up for a long time.	Neck sprain	Low	-.421*	0.036
	X’256	Noise during the fence installation.	Disturbing the comfort of the surrounding environment.	Low	.403*	0.045
	X’266	The cement and sand mixture is too watery.	The plaster falling off does not stick well.	Medium	.577**	0.003
Y3	X’86	Worker pinched by precast wall material during transportation.	Mortality	Medium	.454*	0.012
	X’217	Workers trapped in screed.	Muscle sprain	Low	.402*	0.028
	X’316	The worker's foot was crushed by brick material while lifting.	Muscle sprain	Medium	.398*	0.029
	X’366	Worker hit and/or pinched by a pile of iron pipes.	Head injury	Medium	.387*	0.035

Table 2. KMO & Bartletts test result

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.598
Bartlett's Test of Sphericity	Approx. Chi-Square	583.662
	df	190
	Sig.	0.000

Table 3. Rotated component matrix result

Rotated Component Matrix					Grouping
Var.	Components				
	1	2	3	4	
X'1	0.822	0.325	0.140	-0.096	Factor 1
X'2	0.838	0.189	0.070	-0.387	Factor 1
X'5	0.732	-0.232	0.491	-0.235	Factor 1
X'6	0.509	0.069	0.659	0.093	Factor 3
X'20	0.542	0.353	0.281	-0.073	Factor 1
X'21	0.597	0.204	0.485	-0.242	Factor 1
X'29	0.672	0.153	0.429	-0.259	Factor 1
X'38	0.647	0.163	0.188	-0.511	Factor 1
X'40	0.504	0.616	0.341	0.027	Factor 2
X'45	0.844	-0.009	0.069	-0.153	Factor 1
X'47	0.863	0.243	0.132	0.026	Factor 1
X'94	0.402	0.424	0.553	0.100	Factor 3
X'96	0.136	0.799	0.263	0.015	Factor 2
X'128	0.018	0.915	0.015	-0.265	Factor 2
X'129	0.149	0.867	0.040	-0.131	Factor 2
X'153	0.075	0.336	0.777	0.080	Factor 3
X'171	0.194	0.851	0.289	-0.076	Factor 2
X'256	-0.094	-0.102	0.128	0.871	Factor 4
X'266	-0.267	-0.057	0.005	0.880	Factor 4
a. Rotation converged in 6 iterations.					

3. Results and Discussion

3.1. Correlation Analysis

Correlation analysis was carried out to determine and gauge the strength of the relationship between independent variable X and the dependent Y. Variable X in this research is 382 hazard and risk events in the design and construction phase of the architecture work of a high-rise building project. Meanwhile, the dependent variable Y is obtained from the construction safety performance indicator. The correlation coefficient is used to show the positive or negative relationship.

The basis for decision-making refers to the, where if the Sig. value is below 0.005, and then the variables are not correlated. Meanwhile, when the significance value is above 0.05, the variables are correlated.

An asterisk mark (** or *) will appear when the relationship is relevant. Table 1 describes the outcome of the correlation test.The results in Table 1 show that the strongest correlation between the X and Y variables is Y2 or schedule in construction safety performance indicator. Therefore, in the next process, the X variable used correlates with Y2.

3.2. Factor Analysis

Kaiser-Meyer-olkin Measure (KMO) & Bartlett test provisions for factor analysis are KMO values greater than 0.5 and with a significant value smaller than 0.5. The results of factor analysis in this research are shown in Table 2.

KMO & Bartlett test results for selected variables X and Y2 show sig. value 0.000. The KMO value obtained is 0.598, where this value is greater than the requirement of 0.5 so that the X and Y2 variables are considered sufficient and can be further factor analyzed.

This value is in accordance with the test criteria and can proceed to the rotated component matrix test. The coefficient value of the rotated component matrix is shown in Table 3.Based on Table 3, six iterations of rotation were performed, leading to four component factors forming. The variables were further grouped based on the highest value correlation in each component.

The four new factors are then given names that can represent the characteristics of each member of the variable factor group under study. The following is the naming and grouping of the four factors shown in Table 4.

In factor 1, the variable with the strongest correlation is X'47, where this variable has characteristics related to the collection process by the design team, so naming factor 1 is the competence of the team and data collection.

In factor 2, the variable with the strongest correlation is X'128, where this variable has characteristics related to worker negligence, so naming factor 2 is the negligence of experts and workers are factor 3, the variable with the strongest correlation is X'153 where this variable has characteristics related to workers and materials. Hence, the naming of factor 3 is unsafe work practices.

3.3. Regression Analysis

Regression analysis was used to decide and discover the impact of variable X as an independent variable toward dependent Y2. The four components that have been obtained from the results of factor analysis are regressed using SPSS 26 software, and the results are shown below in Table 5.

The value of adjusted R square from Model 2 and Model 3 are both above 0.5, which could be classified as a valid regression model. The R-square value of Model 3 is the highest among the others, with a confidence level of 66.6% based on the adjusted R-square value. The schedule can be explained by both factors 4, 3, and 2. In Model 2, only 2 factors could explain the relationship between risk towards scheduled programs as an indicator of construction safety performance. Model 1 did not exceed the criteria of the adjusted R-square value so it will be discarded. Table 6 shows the results of ANOVA calculations.

ANOVA results show that all models have marks of the independent variable on the dependent with Sig. value smaller than 0.05. This shows a significant effect on construction safety performance.

In conclusion, all factors have a significant impact on the schedule as variable Y2.The results of the ANOVA test show that model 2 has a higher F value than 3. This is different from the summary model in Table 5, where model 3 is better than model 2. Therefore, it is necessary to analyze the coefficient value of the model to determine the best model to be used in the equation.

Table 7 shows the coefficient value for each model as the result of regression analysis. Table 7 shows that all models have significant values smaller than 0.05. In Model 3, all factors, including 4, 3, and 2, have significant values below 0.05. This means that Model 3 can be used as an equation because it affects schedule in construction safety performance.

Based on all regression analysis processes and the result of the coefficient value, the linear equation is as follows:

$$Y = 2.267 + 0.255(\text{Factor 4}) - 0.246(\text{Factor 3}) - 0.127(\text{Factor 2}) \quad (1)$$

Table 4. Factor analysis grouping result

Variable	Hazard	Risk
Factor 1: Team competency, survey tools, and data source		
Variable	**Hazard**	**Risk**
X'1	Lack of knowledge and capability of the field survey team	Delays in work processes and reports preparation.
X'2	Lack of planning and preparation team personnel	Delays in work processes and reports preparation.
X'5	Experts are not careful in selecting the appropriate survey tool	Inaccurate field survey data
X'20	Survey equipment is not calibrated and falls when used	Field measurement data is inaccurate
X'21	Incomplete weather primary data and literature	Error in site design and building mass
X'29	Very short planning time	Inaccurate design output
X'38	Building master plan is not in accordance with the Regional Spatial Plan (RTRW) and Detailed Spatial Plan (RDTR).	PBG application rejected
X'45	Field survey data is incomplete	Drawings and methods of work inaccurate
X'47	Data sources and literature on unit cost of work in management have not been updated.	Reduced building dimensions and building failure.
Factor 2: Negligence of experts and workers		
Variable	**Hazard**	**Risk**
X’40	Experts are inexperienced in applying design for safety elements.	Experts lack experience in applying design for safety elements in design.
X’96	Design does not consider construction safety aspects.	Design does not consider construction safety aspects.
X’128	Worker's arm was hit by a hammer during thread installation.	Worker's arm was hit by a hammer during thread installation.
X’129	Muscle sprain	Muscle sprain
X’ 171	Workers fall from height	Workers fall from height
Factor 3: Unsafe work practices		
Variable	**Hazard**	**Risk**
X’6	Primary data and literature are outdated	The output of the site design does not comply with the corresponding regulatory requirements.
X’94	Tool-washing sludge and paint residue are disposed of carelessly.	Land and water pollution
X’153	Worker crushed by aluminium frame	Mortality
Factor 4: Method of installation and material composition		
Variable	**Hazard**	**Risk**
X’256	Noise during the fence installation	Disturbing the comfort of the surrounding environment.
X’266	The cement and sand mixture is too watery	Plaster falling off does not stick well

Table 5. Regression analysis result

Models	R-Value	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson Value
1	.566[a]	0.321	0.297	0.377	-
2	.788[b]	0.621	0.593	0.287	-
3	.837[c]	0.700	0.666	0.260	2.055
a. Predictors: (Constant), REGR factor score 4 for analysis 1					
b. Predictors: (Constant), REGR factor score 4 for analysis 1, REGR factor score 3 for analysis 1					
c. Predictors: (Constant), REGR factor score 4 for analysis 1, REGR factor score 3 for analysis 1, REGR factor score 2 for analysis 1					
d. Dependent Variable: Y'2					

Table 6. Result of ANOVA test

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.882	1	1.882	13.228	.001[b]
	Residual	3.984	28	0.142		
	Total	5.867	29			
2	Regression	3.644	2	1.822	22.134	.000[c]
	Residual	2.223	27	0.082		
	Total	5.867	29			
3	Regression	4.109	3	1.370	20.266	.000[d]
	Residual	1.757	26	0.068		
	Total	5.867	29			
a. Dependent Variable: Y'2						
b. Predictors: (Constant), REGR factor score 4 for analysis 1						
c. Predictors: (Constant), REGR factor score 4 and factor score 3 for analysis 1						
d. Predictors: (Constant), REGR factor score 4 for analysis 1, factor score 3, factor score 2 for analysis 1						

Table 7. Coefficient correlation value

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.267	0.069		32.912	0.000
	REGR factor score 4 for analysis 1	0.255	0.070	0.566	3.637	0.001
2	(Constant)	2.267	0.052		43.271	0.000
	REGR factor score 4 for analysis 1	0.255	0.053	0.566	4.782	0.000
	REGR factor score 3 for analysis 1	-0.246	0.053	-0.548	-4.626	0.000
3	(Constant)	2.267	0.047		47.754	0.000
	REGR factor score 4 for analysis 1	0.255	0.048	0.566	5.277	0.000
	REGR factor score 3 for analysis 1	-0.246	0.048	-0.548	-5.105	0.000
	REGR factor score 2 for analysis 1	-0.127	0.048	-0.282	-2.624	0.014

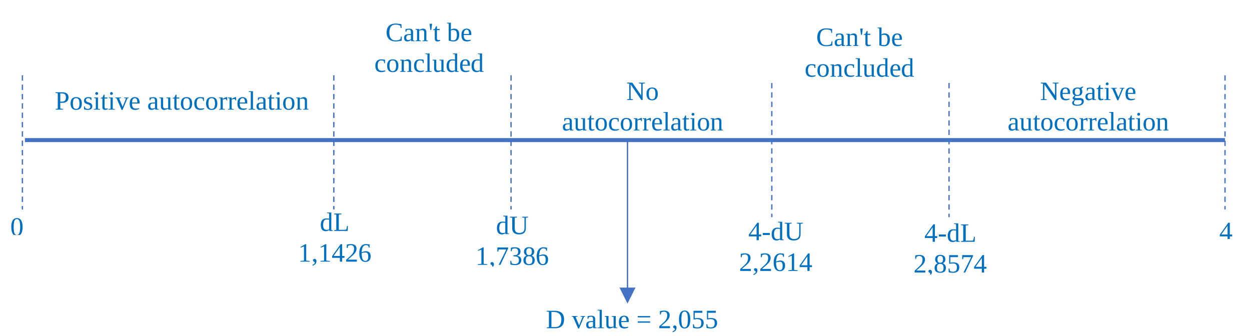

Fig. 1. D value position

The equation model is explained as follows:

- The constant coefficient of the equation is positive 2.267. The absence of risk factors 4, 3, and 2 led to a safe construction performance (Y2); hence, the schedule program increased.
- The regression coefficient of risk factor 4 (Method of installation and material composition) is positive at 0.255. This value shows a positive influence (unidirectional) between variable X in factor 4 and safety performance. An increase in the risk variable in factor 4 will lead to a rise in the Y variable, known as the performance of the scheduled program.
- The regression coefficient of risk factor 3 (Unsafe work practices) is negative 0.246. This value shows a negative influence (opposite direction) between variable X in factor 3 and safety performance. When the risk variable in factor 3 increases, program performance, known as variable Y, decreases.
- The regression coefficient of risk factor 2 (Negligence of experts and workers) is negative 0.127. This value shows a negative influence (between variable X in Factor 2 and safety performance. When the risk variable in factor 2 increases, program performance, known as variable Y, decreases.

3.4. F-Test

The subsequent F-test was carried out to determine the possibility of simultaneous influence among the risk of construction accidents and safety performance. Based on the regression model in the previous section, the hypothesis is as follows:

H0: There is no relationship among the risk of construction accidents in architectural and exterior work of high-rise building integrated design-build contracts and construction safety performance.

H1: There is a relationship among the risk of construction accidents in architectural and exterior work of high-rise building integrated design-build contracts and construction safety performance.H0 is rejected, and H1 is accepted when the F research value is bigger than the F table at a 95% level of confidence of 30 data samples.

The values of F table and F research are 2.76 and 20.266, respectively. This means that F research is greater than the F table; hence, H0 is rejected, and H1 is accepted. Furthermore, there is a simultaneous relationship between the risk of construction accidents in architectural and exterior work of high-rise buildings and integrated design-build contracts with construction safety performance.

3.5. T Test

T test was carried out to determine the impact of factors 4, 3, and 2 partially towards construction safety performance. H0 will be rejected, and H1 will be accepted when the T research value is bigger than the T table value at a 95% confidence level. Based on the regression model in the previous section, the hypothesis is as follows:

H0: There is no relationship among the risk of construction accidents in architectural and exterior work of high-rise buildings integrated with design-build contracts and construction safety performance.

H1: There is a relationship among the risk of construction accidents in architectural and exterior work of high-rise building integrated design-build contracts.

According to the regression test, the values of T research factors 4, 3 and 2 are 5.277, -5.105, and -2.624, respectively. T table value of 2.0595 in factor 4 shows linear influence towards schedule as variable Y. However, both factors 3 and 2 have smaller T research values than the T table. This shows that there is no partial influence from factors 3 and 2 towards variable Y.

There is no relationship among the risk of construction accidents in architectural and exterior work of high-rise buildings. The result is due to the diminutive amount of sample size with a total of 382 variables, which indicated that the test does not have enough power to detect the relationship between variables.

3.6. Durbin Watson Test

Durbin Watson was conducted to determine any aberration and anomaly from the classic autocorrelation assumption. The stipulation of Durbin Watson is as follows:

- When d < dL or d > 4-dL, autocorrelation occurs hence the null hypothesis is rejected.
- When dU < d < (4-dU), there is no autocorrelation; therefore, the null hypothesis is rejected.
- When dL < d < dU or (4-dU) < d < (4-dL), conclusion cannot be drawn.

The test was conducted using 30 data samples with 3 independent variables. According to Table 5, the denomination of Durbin Watson in the regression test is 2.055.

The denominations of Durbin Watson in the table standard are dL = 1.1426 and dU = 1.7386. Based on Fig. 1, the d value is higher than the dU (1.7386 < 2.055 < 2.2614), which meets the second criterion, and it is possible to conclude that model three has no autocorrelation.

4. Discussion

4.1. Quantitative Analysis Discussion

Data collected from the rotated component matrix showed that 19 independent risk variables formed 4 group categories. Each contained latent variables with varying types of risk.

In Factor 1, the Team competency, survey tools, and data source consisted of 9 risk variables, which occurred in the planning phase and significantly impacted material aspects, including design output and construction document. The negligence of experts and workers, comprising 5 variables related to behavior and incompetence in construction phases, was examined in factor 5. Meanwhile, factors 3 and 4 consist of risk variables with more impact on project conditions, including tools, materials, and environment. These factors are caused by worker negligence, with factor 4 used to determine the dominant risk causes in the group. Most of the risks correlated with construction safety performance are induced by workers, as stated in other research.

Risk-impacting workers and project assets or materials have a highly significant relationship to construction safety performance, specifically on the work schedule, than resources or forms of monitoring. This result is in accordance with previous research that stated the predominant cause of construction casualties is the behavior of workers [5,6]. The understanding and awareness of risk or hazard and safety regulation are outlined in preliminary research.

The relationship associated with the equation model formed from the regression analysis has negative coefficient values. The coefficients on factors 4 and 2 are negative, showing an opposite relationship with a decrease in performance when risk variables increase. Although T-test results show some factors are not linearly related, these factors still have an impact on schedule performance. There is a weak relationship between factors 3 and 2, which becomes strong when combined with 4. This shows that risk indicators contained in factor groups 3 and 2 slightly impact the construction work schedule when assessed partially.

This situation can also be caused by dominant external factors that cannot be detected during data collection due to the sample size with a diverse background of job positions. However, based on the Durbin Wattson test outcome, the equation model has been proven to have no autocorrelation. This means that the assessment of the model variance is unbiased, and others do not influence respondent data despite being carried out in different periods.

Based on all the investigations that have been carried out, there is a strong relationship between risk and safety performance. This is because an increase in risk factors will lead to a decrease in scheduling indicator safety performance. The more workers act unsafely, the higher the probability of being crushed by falling material from above, thereby showing a decrease in safety performance. Based on several research, preventive measures are one solution for improving construction safety performance. These include continuously monitoring and assessing the efficacy of preventive and corrective actions, including integrating more risk responses to WBS.

4.2. Qualitative Analysis Discussion

4.2.1. Factor 2: Negligence of Experts and Workers

The concept of design for safety in building design is achievable when experts have sufficient competence regarding construction safety. One of the causes of increased road accidents, besides negligence of workers on the field, is inadequate knowledge and experience [21].A preventative response to safety performance schedule indicators is to provide training time and increase the time for building concept planning. This will enable designers to increase safety-related knowledge related to the materials used and make building components easier to assemble.

Safety outreach, training and toolbox meetings are needed to increase worker awareness during implementation. Routine supervision carries out the volume and type of work associated with the risk posed by this factor.

4.2.2. Factor 3: Unsafe Work Practices

Workers cause unsafe work practices during construction and have been determined to be the main cause of accidents. Accidents affect the lives of workers and also pose the risk of environmental damage. Water pollution is one of the risks of unsafe work practices. This is caused by the indiscriminate disposal of construction waste, such as paint, by workers who did not know that it contained hazardous chemicals and had not been disciplined in waste management [22].

The technique used to prevent the risk of land and water pollution around the project location is through the implementation of procedures for handling and storing hazardous materials [23]. This is in addition to partnering with external parties to manage project liquid waste [23]. The system of cooperation and scheduling supervision is a preventive measure used to ensure that workers always follow applicable regulations.

4.2.3. Factor 4: Method of Installation and Material Composition

The use of wrong methods for mixing or installing materials in the field can harm the environment, leading to water, soil and noise pollution that can disrupt the activities of residents. It not only risks worker injuries but also diminishes the quality of building materials, preventing the achievement of optimal performance.Factors such as work scheduling influence worker behavior, specifically in tasks including mixing and applying plaster to wall surfaces. Due to the large wall area and the plaster mixture potentially hardening quickly, workers tend to add more water than recommended. Therefore, to maintain plastering quality, the time allocated for the work based on the number of workers and the wall surface area needs to be adjusted. Careful scheduling of material installation activities is important to avoid environmental disturbances. Schedule control programs can enhance control measures by adjusting transportation, installation, and welding schedules to avoid busy environmental periods and ensure a smoother work process.

5. Conclusion

In conclusion, this research showed a significant connection between risk factors in construction accidents, identified through WBS of high-rise building projects integrated with design and build contracts. It specifically focused on architectural and exterior work and the impact on construction safety performance. The correlation analysis results showed a strong relationship between risk and schedule, which confirmed a significant impact on construction safety performance through a linear equation model. Although the equation model was not significant in the T-test, the opposite results occurred in the F test and Durbin Watson. The results showed that the tested risk factors were individually significant and stronger when considered. An increase in risk factors would lead to a decrease in scheduling indicator safety performance. The quantitative analysis stated the importance of identifying risk through a detailed WBS for each recorded activity.A comprehensive list of hazards and risks facilitated the risk management process.

This enabled the determination of preventive and corrective actions to reduce the severity of each risk integrated into WBS. From this research, it could be concluded that there was a strong correlation between architectural and exterior WBS integrated design and build contract, effective risk management process and implementation, and construction safety performance. Risk prevention was restricted to preventive and corrective action through WBS and could be achieved through maximizing management and organization performance policies. Therefore, by implementing risk-based WBS and risk management processes the probability of risk would be lowered. This will also improve the construction safety performance of high-rise building projects.

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