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Risk Management Model using Cause and Effect Analysis in Industrial Building Project

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ABSTRACT

The purpose of this study is to determine the main potential risks that occur in the design planning stage of a construction project, especially in an Industrial Building project. Based on the available literature and the experiences of other authors and practitioners, a list of potential risks was developed. Risks events were initially categorized into technical, project management, commercial and external categories. Risks are evaluated by professional practitioners who have experience in construction projects. The evaluation includes the expected likelihood of the event and its impact on changes in scope of work. This study considers each risk among owners, consultants, contractors and others. The data collected were analyzed qualitatively and quantitatively to assess the severity and impact of the event. The recommended responses to major risks are introduced in this study.

***Keywords*:** risk management model, planning stage, industrial building

INTRODUCTION

Risk assessments are necessary to anticipate and prevent accidents from occurring or repeating (Lough, K. G. et al., 2007). Risk event from a different project is different from the risk event on another project. Likewise, the level of occurrence and impact in each project is always changing from one project to another. This makes it difficult for management to handle risks on new projects. Lack of risk management, even inadequate risk analysis, can put construction projects in jeopardy (Basari, I., 2017). According to research by (Awuni, M.A., 2019) revealed that from the 114 consultants only had minimal knowledge about the implementation of risk management at the planning stage. Many respondents know the theoretical knowledge of risk management and its application at the planning stage. There are also many studies that examine risk management at the construction stage or development stage. However, there are rarely studies that discuss risk management at the planning stage. Whereas at this stage most of the major decisions are made which will later affect the success of a construction project. Therefore, this research is very important in order to know the negative impact due to the lack of implementation of risk management at the planning stage.

Construction Project is a process where activity includes different risks that must be handled by all project actors. The planning stage is the initial part of a development project where the project solution is selected from a variety of competitive alternatives that meet the project requirements. This is the stage where the risks associated with a decision can have an impact on the success of a project. In order to minimize the negative consequences of decisions made during the planning stage and to achieve the benefits of the actions taken, appropriate risk management should be used from the early stages of a development project. However, it is common nowadays that the risks in the decision making stage are not considered by project actors in depth, because the capabilities in risk identification, risk assessment and risk management have not been fully developed. Most of the knowledge and experiences of project actors are used in the realization of project development but are rarely associated with risks in decision making or planning. New development projects are not always considered unique and their routines and work schemes accumulate form previous projects without considering the risk and the need for innovation to make the final solution more specific and competitive. Each stage requires good decisions to take further steps towards project success. The negative consequences of decision making will impact several stages of the project. Therefore, risk management is a very important thing to do in a construction project.

LITERATURE REVIEW

Construction Project

Construction project is a process where several groups of people work on the development on buildings from concept to development. The project is divided into several stages where the project actors focus on development according to the roles or responsibilities that have been determined.

According to (Chan, A.P.C. and Chan, A.P.L., 2004), construction projects have many often conflicting objectives that must be met in order for a project to be considered a success. Project goals are dynamic, and success means different things to people at different points in the project life cycle.

Risk Management

According to (Djohanputro, B., 2008) risk management is a structured and systematic process in identifying, measuring, mapping, developing alternative risk management, and monitoring and controlling risk management. Risk management is the art and science of anticipating and planning for future uncertain events. It is concerned with identifying and analyzing a range of possible outcomes, then control and mitigate their negative impacts. The objective is to understand, and mitigate or control risks (Sakthiniveditha, V., 2015).

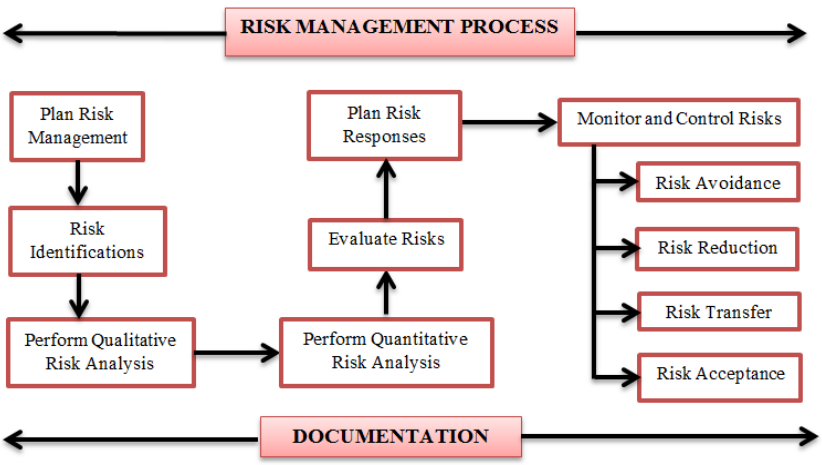

Fig. 1. Risk Management Process

Risk Assessment

Table 1. Probability Scale (AS/NZS 4360 : Risk Management, 2004)

Level	Occurence	Description
1	Very Unlikely	Almost never happen
2	Unlikely	Possible, but rare
3	Possible	Can occur under certain condition
4	Likely	Can happen periodically
5	Almost Certain	Can happen anytime

Table 2. Severity Scale (Anitasari & Wessiani, 2011)

Level	Impact	Description
1	Insignificant	Low financial loss
2	Minor	First aid treatment, medium financial loss
3	Moderate	Medical treatment required, high financial loss
4	Mayor	Extensive injuries, loss of production capability, major financial loss
5	Catastrophic	Death, huge financial loss

Table 3. Risk Assessment Matrix (AS/NZS 4360 : Risk Management, 2004)

Probability	**Consequences**				
	1 (Insignificant)	**2 (Minor)**	**3 (Moderate)**	**4 (Mayor)**	**5 (Catastrophic)**
1 (Very Unlikely)	LOW	LOW	LOW	LOW	MEDIUM
2 (Unlikely)	LOW	LOW	MEDIUM	MEDIUM	MEDIUM
3 (Possible)	LOW	MEDIUM	MEDIUM	MEDIUM	HIGH
4 (Likely)	MEDIUM	MEDIUM	MEDIUM	HIGH	HIGH
5 (Almost Certain)	MEDIUM	MEDIUM	HIGH	HIGH	HIGH

Cause and Effect Analysis

Cause and Effect Analysis is a structured method to identify the possible risk of complex problems that present several interrelated causes (Lorenada, E.M., 2017). This method classifies the causes of a risk into categories to facilitate identification. This cause information is shown in a fishbone diagram or an Ishikawa diagram. For building a fishbone chart we use arrows or branches: (1) primary branch: represents the effect, (2) major branch: corresponds to the major cause, (3) minor branch: corresponds to the causative and more detailed factors.

MATERIALS & METHODS

The research is focus on the risks posed by lack of knowledge or not applying risk management at the planning stage. The purpose of this research is to find the most potential risks that occur in the planning stage of a construction project, especially in the Industrial Building Project.

The risk is evaluated by professional practitioners who have experience in construction projects. The evaluation includes the expected probability of the event and is impact on changes in the scope of work. This study considers each risk among owners, consultants, contractors and others. The data collected is analyzed qualitatively and quantitatively to assess the severity and impact of the event.

The potential risks were identified by the authors based on the available published researches and the interview carried out with experts. The risks were categorized from the Risk Breakdown Structure (PMBOK 6th Edition, 2017) in four major groups, including:

Table 4. Risk Factor in Industrial Project

Main Factor	Categories	Variable	Sub Factor	Reference
Technical Risk (X1)	Process	X1.1	Site Investigation	Sutoyo (2000)
		X1.2	Completeness data of the site conditions	Muhharam Noor (2006)
		X1.3	Completeness of data to make DED (Detail Engineering Design)	Documment reviews
	Design	X1.4	Error in design	Candra Y. (2017)
		X1.5	Completeness of DED	CII (1997)
	Technology	X1.6	Error due to software used	Hosen (2006)
Project Management Risk (X2)	Scheduling	X2.1	Limited time to prepare for tender	Ogulana (2003)
	Estimate	X2.2	Material specification that are less detailed and less accurate	Soeharto (1997)
		X2.3	BOQ calculation that is not accurate	Wideman (1992)
	Planning	X2.4	Inconsistency between construction plans and field implementation	Ali K. (2017)
	Communication	X2.5	Lack of coordination between engineering team	G. B. Oberlander (1993)
		X2.6	Lack of coordination between design team	Vichian
		X2.7	Lack of coordination between several disciplines	Karim El-Dash (2006)
		X2.8	Communication between Owner and the design team	Muhammad Saqib (2008)
	Resources	X2.9	Lack of Estimator's experience	Callahan MT (1992)
		X2.10	Lack of designer's experience	Wideman (1992)
		X2.11	Lack of Engineer's experience	Ogulana (2003)
		X2.12	There are no consultants for special disciplines	Karim El-Dash (2006)
	Prioritization	X2.13	No quality control system	Karim El-Dash (2006)

Table 4 Continued...				
Commercial Risk (X3)	Subcontractors	X3.1	Contractor's experience	C. K Ho (2001)
	Suppliers	X3.2	Machine vendor/ supplier change	Docmment reviews
		X3.3	Change in the shape, size, location of the machine	Docmment reviews
	Client/ Customers	X3.4	Design changes by Owner (addition / subtraction)	Karim El-Dash (2006)
		X3.5	Owner doesn't fully explain his needs	Anik R. (2018)
External Risk (X4)	Regulatory	X4.1	Inflation and price fluctuations that cause cost overruns from the original plan	Yu Sun (2008)
		X4.2	Industry standard compliance	CII (1997)
		X4.3	Change in the government's political and economic situation or policies	Muhammad Saqib (2008)
	Market	X4.4		Anik R. (2008)
		X4.5	Increase in labor costs, material price and equipment price	Gusti A.(2015)
Cost Factor (Y)	Cost Efficiency	Y1	Application of Value Engineering	Karim El-Dash (2006)
		Y2	Application of Lean Construction	Document reviews

The table above is a list of risk factor that will be tested for expert validity and carried out a pilot survey before a questionnaire is made and distributed to respondents.

RESULT

From the results of statistical analysis, a finding will be obtained in this study. In the research process, standards were achieved based on secondary data analysis which was translated into research variables will be the basis and reference for obtaining results from primary data (questionnaire) so that the objectives of the research can be achieved. Data processing for the results of the questionnaire survey was analyzed using SPPS version 25 software.

Statistical Analysis

Validity and Reliability Test

The r-table value with a significance level used 5% obtained r-table Product Moment df = 31-2 = 0.355. The validity test results of the factors causing change orders on time and cost performance show valid variables because of the value of r-table > 0.355.

The reliability test in this study uses the internal reliability coefficient of alpha, the questionnaire questions can be said to be reliable if the Cronbach's Alpha coefficient is above 0,6. The results of the reliability test can be seen in the table below:

Table 5. SPSS reliability test Case Proccesing Summary

Case Processing Summary			
		N	%
Cases	Valid	35	100,0
	Excluded[a]	0	,0
	Total	35	100,0
a. Listwise deletion based on all variables in the procedure.			

(Source. Analysis Results, 2021)

Table 6. SPSS reliability test Reliability Statistics

Reliability Statistics	
Cronbach's Alpha	N of Items
,918	31

(Source. Analysis Results, 2021)

Reliability testing was processed using the Statistical Package for Social Science (SPSS) software. The results of the reliability test on the risk factors are 0.918, as in table 3. Therefore, 0.903> 0.60 so that the questionnaire instrument is valid.

Multinomial Logistic Regression Test

The multinomial logistic regression test is a regression model used to solve regression cases with the dependent variable in the form of multinomial with one or more independent variables.

Indicator:

P-value < α (0,05)

Table 7. SPSS Regression Multinomial Logistic Test Result X1 and Y

Model Fitting Information				
Model	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	70,193			
Final	33,641	36,552	14	,001

(Source. Analysis Results, 2021)

Table 8. SPSS Regression Multinomial Logistic Test Result X2 and Y

Model Fitting Information				
Model	**Model Fitting Criteria**	**Likelihood Ratio Tests**		
	-2 Log Likelihood	**Chi-Square**	**df**	**Sig.**
Intercept Only	70,193			
Final	,000	70,193	28	,000

(Source. Analysis Results, 2021)

Table 9. SPSS Regression Multinomial Logistic Test Result X3 and Y

Model Fitting Information				
Model	**Model Fitting Criteria**	**Likelihood Ratio Tests**		
	-2 Log Likelihood	**Chi-Square**	**df**	**Sig.**
Intercept Only	71,988			
Final	32,573	39,415	15	,001

(Source. Analysis Results, 2021)

Table 10. SPSS Regression Multinomial Logistic Test Result X4 and Y

Model Fitting Information				
Model	**Model Fitting Criteria**	**Likelihood Ratio Tests**		
	-2 Log Likelihood	**Chi-Square**	**df**	**Sig.**
Intercept Only	77,169			
Final	48,609	28,560	15	,018

(Source. Analysis Results, 2021)

Table 11. Risk Level Assessment

Main Factor	Variable	Risk Factor	Means	Risk Level
Technical Risk Factor (X1)	X1.1	Site Investigation	17,6	H
	X1.2	Completeness data of the site conditions	19,4	H
	X1.3	Completeness of data to make DED (Detail Engineering Design)	17,4	H
	X1.4	Error in design	17,8	H
	X1.5	Completeness of DED (Detail Engineering Design)	18,2	H
	X1.7	Error due to software used	10,1	L
Project Management Risk Factor (X2)	X2.1	Limited time to prepare for tender	17,5	H
	X2.2	Material specification that are less detailed and less accurate	15,2	M
	X2.3	BOQ calculation that is not accurate	15,5	M
	X2.5	Inconsistency between construction plans and field implementation	18,3	H
	X2.6	Lack of coordination between engineering team	16,0	M
	X2.7	Lack of coordination between design team	14,7	M
	X2.8	Lack of coordination between several disciplines	15,6	M
	X2.9	Communication between Owner and the design team	16,3	M
	X2.10	Lack of Estimator's experience	12,9	L
	X2.11	Lack of designer's experience	15,1	M
	X2.12	Lack of Engineer's experience	15,8	M
	X2.13	There are no consultants for special disciplines	12,2	L
	X2.14	No quality control system	17,2	H
Commercial Risk Factor (X3)	X3.1	Contractor's experience	13,4	L
	X3.2	Machine vendor/ supplier change	18,7	H
	X3.3	Change in the shape, size, location of the machine	19,6	H
	X3.4	Design changes by Owner (addition / subtraction)	20,4	H
	X3.5	Owner doesn't fully explain his needs	16,9	M
External Risk Factor (X4)	X4.1	Inflation and price fluctuations that cause cost overruns from the original plan	13,1	L
	X4.2	Industry standard compliance	14,0	M
	X4.3	Change in the government's political and economic situation or policies	12,4	L
	X4.4	Lack of materials	13,8	M
	X4.5	Increase in labor costs, material price and equipment price	13,5	L
Cost Factor (Y)	Y1	Application of Value Engineering	14,5	M
	Y2	Application of Lean Construction	16,2	M

(Source. Analysis Results, 2021)

CASE STUDY

Pareto Analysis

At this stage, the work items are classified into similar work items and then sort them form the highest cost to the lowest cost in order to facilitate the research and a pareto distribution graph is made, by determining 80% of the total additional work as the root of the next analysis.

Table 12. Change in scope of work

No.	Work Item	Total Price	Percentage	Cumulative (%)
1.	Creamer Tower	4.104.280.809	27,14%	27,14%
2.	Operational	2.386.881.362	15,78%	42,92%
3.	WTP, Carbon Tank & GWT	1.644.610.901	10,87%	53,79%
4.	WWTP	1.367.572.304	9,04%	62,83%
5.	Instant Tower	1.047.279.681	6,92%	69,75%
6.	Boiler	1.029.031.972	6,80%	76,55%
7.	Chiller	626.916.656	4,14%	80,69%
8.	Silo Debora	551.683.950	3,65%	84,34%
9.	RAW Material Warehouse	474.332.216	3,14%	87,48%
10.	Front Road MDC	346.122.471	2,29%	89,77%
11.	Mosque & Clinic	289.043.289	1,91%	91,68%
12.	Panel Room & Genset	224.573.458	1,48%	93,16%
13.	STP	211.580.047	1,40%	94,56%
14.	Office connecting ladder	210.841.247	1,39%	95,95%
15.	Office	155.564.202	1,03%	96,98%
16.	Guardhouse	125.025.987	0,83%	97,81%
17.	Canteen	120.762.945	0,80%	98,61%
18.	Utility	91.254.282	0,60%	99,21%
19.	Gas & Compressor Building	52.664.880	0,35%	99,56%
20.	Operator room & brigde	35.854.004	0,24%	99,80%
21.	Forklift Track	19.561.112	0,13%	99,93%
22.	Rotary Dryer	9.334.539	0,06%	99,99%
23.	Flagpole	534.053	0,001%	**100%**
Total		**11.834.982.070**	**100%**	

From the table above, the Pareto Diagram has been carry out:

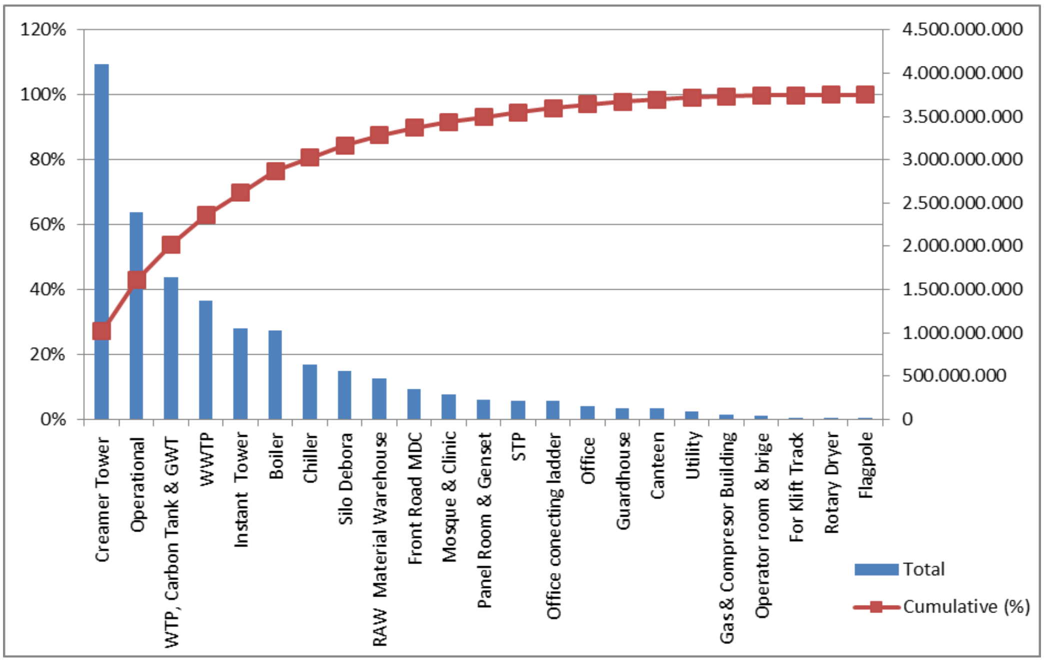

Fig. 2 Pareto Diagram

From the table above, 7 work items are selected that have significant influence on change scope of work, which will then be used in the analysis using a Cause and Effect diagram.

Cause and Effect Analysis Method

The following is a Cause and Effect diagram from a case study that has been carried out based on Pareto diagram. It can be seen that the main events greatly affect changes in the scope of work. Therefore, the Cause and Effect diagram is used to determine the cause of the event.

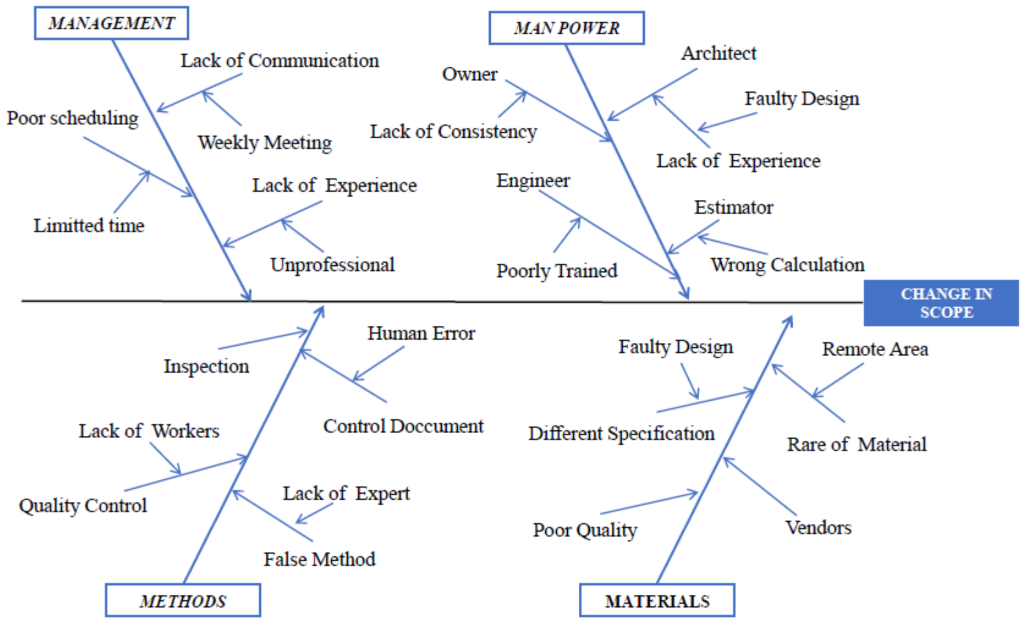

Fig. 3 Cause and Effect Diagram

From the Cause and Effect diagram above, it can be seen that the causes are risk factors that greatly affected in the change scopes of work. These risk factors become the dominant factors which will later be given preventive measures.

DISCUSSION

Risk Register

Table 12. Risk register

Risk Level	Rank	Variable	Risk Factor	Risk Response
High	1	X3.4	Design changes by Owner (addition / subtraction)	Risk Avoidance
	2	X3.3	Change in the shape, size, location of the machine	
	3	X1.2	Completeness data of the site conditions	
	4	X3.2	Machine vendor/ supplier change	
	5	X2.5	Inconsistency between construction plans and field implementation	
	6	X1.5	Completeness of DED (Detail Engineering Design)	
	7	X1.4	Error in design	
	8	X1.1	Site Investigation	
	9	X1.3	Completeness of data to make DED (Detail Engineering Design)	
	10	X2.1	Limited time to prepare for tender	
	11	X2.14	No quality control system	
Medium	12	X3.5	Owner doesn't fully explain his needs	Risk Reduction
	13	X2.9	Communication between Owner and the design team	
	14	Y2	Appication of Lean Construction	
	15	X2.6	Lack of coordination between engineering team	
	16	X2.12	Lack of Engineer's experience	
	17	X2.8	Lack of coordination between several disciplines	
	18	X2.3	BOQ calculation that is not accurate	
	19	X2.2	Material specification that are less detailed and less accurate	
	20	X2.11	Lack of desainer's experience	
	21	X2.7	Lack of coordination between design team	
	22	Y1	Application of Value Engineering	
	23	X4.2	Industry standard compliance	
	24	X4.4	Lack of materials	
Low	24	X4.5	Increase in labor costs, material price and equipment price	Risk Acceptance/ Risk Transfer
	25	X3.1	Contractor's experience	
	27	X4.1	Inflation and price fluctuations that cause cost overruns from the original plan	
	28	X2.10	Lack of Estimator's experience	
	29	X4.3	Change in the government's political and economic situation or policies	
	30	X2.13	There are no consultants for special disciplines	
	31	X1.7	Error due to software used	

(Source. Analysis Results, 2021)

Risk Response

From the results of the research using questionnaires and case study, it is found that several factors are very influential in the change in scope of work in Industrial Building Project. And preventive measure should be taken for the dominant risk factor. The following is a table of dominant risk factor and how to prevent it.

Table 13. Dominant Risk Factor and Risk Response

Variable	Dominant Risk Factor	Risk Response
X3.4	Design changes by Owner (addition / subtraction)	At the time of planning, the project manager should make a list of what needs are needed by the Owner to minimalize the design change.
X3.3	Change in the shape, size, location of the machine	Ensure the specificatoins of the machine used are in accordance to the need Conducting survey regarding the need of related machine
X1.2	Completeness data of the site conditions	Conduct a site as detailed as possible Remeasure the site
X3.2	Machine vendor/ supplier change	Ensure a trusted and familiar machine vendor or supplier
X2.5	Inconsistency between construction plans and field implementation	Conduct weekly meeting to minimize change in the design Design team should be someone who experienced in similar project
X1.5	Completeness of DED (Detail Engineering Design)	Make a list of DED to check after the drawings are complete
X1.4	Error in design	Implement a quality control system in each team
X1.1	Site Investigation	Site survey must be carried out by the design team so that they can be more accurate in making Detail Engineering Design
X2.1	Completeness of data to make DED (Detail Engineering Design)	Ensure that all documents neededfor planing are complete Completing the missing data
X1.3	Limited time to prepare for tender	Tender should not be prepare in a short time Recruit more peope in the planning team
X2.14	No quality control system	Make a quality control team Require the Project Manager to carry out inspections

(Source. Analysis Results, 2021)

CONCLUSION

Based on the results of research and processing of secondary data, the conclusions can be drawn as follow:

1. From the results of the statistical tests, it is known that the most significant factors that affect change in scope of work in Industrial Building project are: (X2) project management risk factors and (X1) technical risk factors.
2. From the results of the risk assessment obtained 11 risk factors that have a high risk in influencing the change in scope of work in Industrial Building project, namely: (X3.4) Design changes by Owner, (X3.3) Change in the shape, size, location of the machine, (X1.2) Completeness data of the site conditions, (X3.2) Machine vendor/ supplier change, (X2.5) Inconsistency between construction plans and field implementation, (X1.5) Completeness of DED, (X1.4) Error in design, (X1.1) Site Investigation, (X2.1) Completeness of data to make DED, (X1.3) Limited time to prepare for tender, and (X2.14) No quality control system.

Form the results of the study, it can be concluded that the planning stage of a construction project, especially Industrial Building Project has very important influence in the change in scope of work. Therefore, risk management should be carried out as early as possible, namely at the planning stage.

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