Risk Analysis To Improve Time Performance Of The Procurement And Installation Of Elevator

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Abstract- During the procurement and installation of elevators, frequent problems occurred which delayed the completion of the elevator installation. The aim of the study is to analyze the dominant risk factors that influence the procurement and installation of elevators at PT. X which affects the time performance of elevator installation. Risk analysis was conducted based on PMBOK 2017, using the concept of probability and impact matrix. The risk factors identification process was performed using the literature study and archival analysis of PT X. Identified risk factors then validated by experts. After validating the risk factors, a questionnaire was distributed to respondents who were practitioners in the elevator field. The collected data then processed and analyzed to obtain the dominant risk factors that affect the on-time performance. The results showed that there were 4 dominant risk factors in the elevator procurement process with a medium risk level. 20 dominant risk factors in the elevator installation process with a medium risk level. The result of this study can help project managers in elevator company identify the risks associated with procurement and installation process which affects the time the time performance.

Index Terms- Elevator procurement and installation process, Delay, Risk factors, Risk analysis.

I. Introduction

Today high rise buildings have one or more elevators a vertical transportation. Many people use elevator in numerous buildings such as business centers, hotels, hospitals, and shopping centers every day (Yaman, Baygin, & Karakose, 2016). Elevators are a vertical transportation system that is very important for the easy and comfortable movement of people or goods from floor to floor in high-rise buildings (Shukla, & Tambe, 2018). An elevator is an elevator that has a car and a counter weight moves up and down following guide rails that are permanently installed on buildings, has a governor and is used to transport people and/or goods (Regulation of Minister of Labor Republic of Indonesia Number 6 of 2017, State Gazette of the Republic of Indonesia Indonesia, 2017). An increasing number of such buildings increase the demand for elevator installation.

Although the demand, there are frequent problems that occur during elevator installation. Several studies have identified problems that cause time delays in the completion of elevator installations. Vieira and Weiss (2021) have identified major problems in elevator installation in Brazil. Such as unsynchronized delivery of equipment and materials to the installation site, low qualifications of the installation team, inadequate completion of IRF 1, 2, and 3 by the installation team, replacement of missing and out-of-specification materials taking too long, various problems during the distribution of materials at the installation site and installation quality problems resulting in rework.

Suwankanit (2019) identified 3 failure modes that affect the completion time of elevator installation in Thailand. such as the hoistway structure not straight from the pit to the overhead. The opening structure not straight from the pit to the overhead and the error in making the hoistway door open and blocking out the opening structure.

Azambuja, Isatto, Marder and Formoso (2006) have identified problems in the elevator procurement process that affect the completion time of elevator installation in Brazil. For example, the sales department did not define elevator specifications completely and made incomplete and incorrect orders to the factory. Changes in elevator dimensions or specifications were not informed to the factory. There were no working drawings at the job site. The information submitted to the main contractor was unclear and not detailed, especially electrical problems for work and for the process of the slow-speed and high-speed elevator. Information about the condition of the work area was not informed to the factory, making it impossible to anticipate potential problems during installation, and inadequate and inappropriate storage locations.

Heikilla (2019) explains the problems of elevator installation in general. Such as the problem of limited material storage space which requires the materials to be stacked, this causes difficulties for the installation team to pick up and move the 3 materials needed. Material delivery errors caused by unclear information contained in the list of materials contained in the elevator crates. So that the installation team don't know what materials are contained in the crates and must dismantle the crates first to find the required materials and also some elevator materials sent are not standard.

Constraints that occur in elevator installations indicate risk. Risk is an uncertain event or uncertain condition that, when it occurs, will have a positive or negative impact on one or more project objectives (PMI, 2017). To minimize negative risks, risk management is required. Project risk management is the art and science of identifying, assessing and responding to project risk throughout the life of a project and in thebest interests of its objectives (Wideman, 1992). The goal of project risk management is to increase the likelihood and impact of positive events and reduce the likelihood and impact of negative events in the project (PMI, 2017). Martinelli and Milosevic (2016) state that risk management is a preventive measure that allows project managers to identify potential problems before they occur and take corrective action to avoid or reduce the impact of risks. Ultimately this behavior allows project teams to accelerate project cycles at a much faster pace.

The problems identified above also occur in PT. X as one of the elevator distributors in Indonesia which results in time delays in the completion of the elevator installation. This study aims to analyze the dominant risk factors that influence the procurement and installation process of elevators at PT. X which affect the time-performance of the elevator installation. To achieve the research aim, two research question has been developed :

1). How is the implementation of elevator procurement and installation work at PT. X ?
2). What are the risk factors in the implementation of elevator procurement and installation work at PT. X?

II. RESEARCH METHODOLOGY

The research used mixed methods. The first research question was achieved using secondary data through a desk study and archival research in order to identify the guidelines for the implementation of procurement and installation of elevators implemented at PT. X and then validate the risk factors from experts.

After the risk factors get validation, it is then made into question items in the form of a questionnaire. The second research question was achieved using the questionnaire as primary data from respondents who were practitioners in the elevator field. The questionnaire is used to identify risk factors that occur in the implementation of elevator procurement and installation at PT. X and then analyzed using Kruskal-Wallis test and probability impact matrix.

Probability impact matrix is a method to qualitatively analyze the risks posed by creating an index scale. There are four steps to develop the index scale :

1. Find the probability value by multiplying the number of respondents' answers on each probability scale with the probability scale value and then sum it up.
2. Find the impact value by multiplying the number of respondents' answers on each impact scale with the impact scale value and then summing them up. impact scale with the impact scale value and then sum it up.
3. Find the risk value obtained from the result of multiplying the average probability (P) by the average impact (I).
4. Classify the risk level by mapping the risk value into a probability and impact matrix (PMBOK, 2017).

The probability and impact matrix can be shown in Figure 1.

Figure 1. Probability Impact Matrix with Scoring Scheme

Probability	Threats					Opportunities					Probability
Very High 0.90	0.05	0.09	0.18	0.36	0.72	0.72	0.36	0.18	0.09	0.05	Very High 0.90
High 0.70	0.04	0.07	0.14	0.28	0.56	0.56	0.28	0.14	0.07	0.04	High 0.70
Medium 0.50	0.03	0.05	0.10	0.20	0.40	0.40	0.20	0.10	0.05	0.03	Medium 0.50
Low 0.30	0.02	0.03	0.06	0.12	0.24	0.24	0.12	0.06	0.03	0.02	Low 0.30
Very Low 0.10	0.01	0.01	0.02	0.04	0.08	0.08	0.04	0.02	0.01	0.01	Very Low 0.10
	Very Low 0.05	Low 0.10	Moderate 0.20	High 0.40	Very High 0.80	Very High 0.80	High 0.40	Moderate 0.20	Low 0.10	Very Low 0.05	
	Negative Impact					Positive Impact					

5. After each variable is mapped into the probability and impact matrix, the next step is determining the risk level as shown in Figure 2.

Figure 2. Risk Level

Risk Level	Scale
Low Risk	0,01 – 0,07
Medium Risk	0,08 – 0,20
High Risk	0,24 – 0,72

III. DATA COLLECTION AND ANALYSIS

Data collection in this study was carried out in two stages
Data collection stage 1 is carried out through literature studies and archive analysis to identify guidelines for the procurement and installation of elevators. After the guidelines for the implementation of the procurement and installation of elevators were identified, then the guidelines were validated by experts. Validation was carried out by 3 experts. The expert profile can be seen in table 1.

Table 1. The Expert Profile

No	Expert	Position	Work Experience	Education Level
1.	Expert 1	Operational Manager	17 Years	Master degree
2.	Expert 2	Service Field Director	25 Tahun	Master degree
3.	Expert 3	Head Of Construction Department	17 Tahun	Bachelor degree

The results of the expert validation became a guideline for the implementation of the procurement and installation of elevators in this study. The results of the expert validation became guidelines for the implementation of the procurement and installation of elevators in this study. The approved guidelines on the process of implementing the procurement and installation of elevator can be seen in table 2 and table 3.

Table 2. Implementation Of Elevator Procurement Process

I. Implementation of elevator procurement process	
Variabel	**Indicator**
I.1.	**Negotiation**
X1.1	Define the elevator specifications and make sales proposals
X1.2	Create layout drawing
I.2.	**Approval of proposals and award of contracts by the owner**
X1.3	Approval of proposals and award of contracts by the owner
I.3.	**Booking**
X1.4	Create design drawing for production
X1.5	Design elevator approval by owner
X1.6	Sending specifications of elevators to be produced to the factory
X1.7	Elevator ordering by the E-log team
I.4.	**Fabrication**
X1.8	Elevator fabrication by elevator manufacturers
I.5.	**Elevator delivery from factory to project site (MOS)**
X1.9	Elevator delivery from factory to project site (MOS)

Table 3. Implementation Of Elevator Installation Process

II. Implementation of Elevator Installation Process	
Variabel	**Indicator**
I.1.	**Preparation**
X2.1	Create working methods
X2.2	Coordination with the main contractor regarding the availability of electrical power for elevator installation
X2.3	Create the installation schedule
X2.4	Make a list of work equipment
X2.5	Make a list of installation team
X2.6	Installation of work equipment
X2.7	Pre-start checklist and handover hoistway from main contractor to elevator contractor
I.2.	**EHS Audit**
X2.8	Audit request to the EHS team
X2.9	Audit by EHS team regarding preparations to start installation
I.3.	**Installation**
X2.10	Plumbline template settings
X2.11	Rail installation stage 1
X2.12	Elevator car installation
X2.13	Installation of the device elevator in the machine room
X2.14	Working platform installation
X2.15	Installation of counterweight frames, ropes and filler weight
X2.16	Installation of traveling cables, tension and rope governors

X2.17	Low speed by adjuster
X2.18	Rail installation stage 2
X2.19	Hoistway doors installation
X2.20	Installation of hoistway and pit devices
X2.21	Highspeed process by adjuster
X2.22	Elevator accessories installation
I.4.	**Quality control**
X2.23	Request for quality check to QC department
X2.24	Quality check by QC department
I.5.	**Test and Commissioning**
X2.25	Test and commissioning with owner
I.6.	**Handover of the unit to the owner**
X2.26	Handover of the unit to the owner

Data collection stage 2 is carried out through literature studies and archive analysis to identify the risk factors involved in the procurement and installation of elevators. After the risk factors are identified then the risk factors are validated by experts. The results of the expert validation show that of 11 factors identified through literature study and archive analysis, the experts agree that 11 factors are risk factors involved in the procurement of elevators. The results of the expert validation also showed that of 39 risk factors identified through literature studies and archive analysis, 38 risk factors were approved by the experts.

The approved variabel of the risk factors in the process of implementing the procurement and installation of elevators can be seen in table 4 and table 5.

Table 4. Risk Factors in The Implementation Of Elevator Procurement

No.	Variabels	Indicator
I.1.	**Negotiation**	
1.	X3.1	Lack of information on design requirements
2.	X3.2	Some of the materials delivered did not meet specifications due to sales errors
3.	X3.3	Some materials were not delivered due to sales errors
I.2.	**Proposal approval and contract award by owner**	
1.	X3.4	The scope of work in the contract is not clear
I.3.	**Booking**	
1.	X3.5	Some of the materials delivered did not meet specifications due to e-log errors
2.	X3.6	Some materials were not delivered due to e-log errors
I.4.	**Fabrication**	
1.	X3.7	Some of the materials delivered did not meet specifications due to factory errors
2.	X3.8	Some materials were not delivered due to factory errors
I.5.	**Material On Site**	
1.	X3.9	Some of the materials delivered did not meet specifications due to factory errors
2.	X3.10	Some materials were not delivered due to factory errors
3.	X3.11	Some of the materials delivered did not meet specifications due to factory errors

Table 5. Risk Factors in The Implementation Of Elevator Installation

No	Variabel	Indicator
II.1.	**Preparation**	
1	X4.1	Delay in the work tools
2	X4.2	Delay delivery of tools to the project
3	X4.3	Stock of required safety and work tools is missing
4	X4.4	Power supply is not available
II.2.	**EHS Audit**	
1	X4.5	Pit, shaft, machine room and the area arround installation conditions are still potentially hazardous
2	X4.6	Installation of work and safety equipment is not standardized
II.3.	**Installation Process**	
1	X4.7	The dimension of hoistway, machine room and pit do not match the required dimensions
2	X4.8	Damage tools during installation elevator
3	X4.9	Placement of material in the crate does not match the list listed on the material crate
4	X4.10	Setting the plumb line template incorrectly
5	X4.11	Disputes with other contractors

6	X4.12	Material damage
7	X4.13	Rework
8	X4.14	Poor EHS management in the site
9	X4.15	Low quality of labor
10	X4.16	Lack of competent labor
11	X4.17	Low of labor motivation
12	X4.18	Low of labor productivity
13	X4.19	Labor dispute
14	X4.20	Non standard measuring tools
15	X4.21	Poor coordination within thee team
16	X4.22	Poor external coordination
17	X4.23	Loss of elevator material during installation
18	X4.24	Elevator electrical component problem
19	X4.25	New elevator system
20	X4.26	Delay in payment of work progress
21	X4.27	Delay in payment of workers wage
22	X4.28	Slow internal decision making
23	X4.29	Late start of project implementation
24	X4.30	Poor supervision
25	X4.31	Too many projects being handled at the same time
26	X4.32	Delay delivery of materials to the project site
27	X4.33	Wrong survey
28	X4.34	Incorrect method
II.3.	**Quality Check**	
1	X4.35	QC check are carried out repeatedly
II.4.	**Test and Commissioning**	
1	X4.37	Recurring checklist with the owner
2	X4.38	Several elevator components were damaged and not active during test and commissioning
II.5.	**Handover of the unit to the owner**	
1	X4.39	Supporting documents for the handover process are incomplete

After expert validation then survey respondents with questionnaires was carried out. The respondent profile can be seen in table 6.

Table 6. Respondent Profile

Responden	Position	Work Experience (Years)	Education Level
R1	Site Manager	10	Bachelor Degree
R2	Site Manager	7	Associate Degree
R3	Project Engineer	8	Bachelor Degree
R4	Project Engineer	9	Bachelor Degree
R5	Site Manager	5	Associate Degree
R6	Mechanic Leader	12	Senior High School
R7	Site Manager	15	Bachelor Degree
R8	Project Manager	10	Bachelor Degree
R9	Site Manager	7	Bachelor Degree
R10	Site Manager	7	Senior High School
R11	Project Manager	7	Associate Degree
R12	Project Engineer	6	Bachelor Degree
R13	Site Manager	6	Senior High School
R14	Project Engineer	15	Bachelor Degree
R15	Site Manager	5	Bachelor Degree
R16	Project Manager	21	Bachelor Degree
R17	Project Manager	10	Master Degree
R18	Project Engineer	7	Bachelor Degree
R19	Project Engineer	5	Bachelor Degree
R20	Mechanic Leader	12	Senior High School
R21	Site manager	13	Bachelor Degree
R22	Project Engineer	13	Master Degree
R23	Site Manager	5	Senior High School
R24	Site Manager	19	Senior High School

R25	Site manager	10	Associate Degree
R26	Project Engineer	9	Bachelor Degree
R27	Project Manager	7	Bachelor Degree
R28	Site Manager	10	Bachelor Degree
R29	Project Engineer	5	Bachelor Degree
R30	Site Manager	5	Senior High School

Recapitulation of data from the results of the respondent's questionnaire in the implementation of the elevator procurement can be seen in table 7 and the implementation of the elevator installation can be seen in table 8.

Table 7. Recapitulation of data from the results of the respondent's questionnaire in the implementation of the elevator procurement

I. Implementation Of Elevator Procurement													
Variable	Indicator	Probability (P)						Impact (I)					
		1	2	3	4	5	SUM	1	2	3	4	5	SUM
I.1.	**Negotiation Process**												
X3.1	Lack of information on design requirements	7	8	7	5	3	30	2	11	6	6	5	30
X3.2	Some of the materials delivered did not meet specifications due to sales errors	7	9	8	4	2	30	4	6	8	11	1	30
X3.3	Some materials were not delivered due to sales errors	9	6	10	4	1	30	7	3	9	7	4	30
I.2.	**Proposal approval and contract award by owner**												
X3.4	The scope of work in the contract is not clear	6	5	8	6	5	30	3	6	6	4	11	30
I.3.	**Booking**												
X3.5	Some of the materials delivered did not meet specifications due to e-log errors	14	6	7	2	1	30	10	6	4	7	3	30
X3.6	Some materials were not delivered due to e-log errors	13	6	6	3	2	30	11	5	6	4	4	30
I.4.	**Fabrication**												
X3.7	Some of the materials delivered did not meet specifications due to factory errors	12	12	3	2	1	30	10	6	7	3	4	30
X3.8	Some materials were not delivered due to factory errors	15	5	4	5	1	30	11	5	5	5	4	30
I.4.	**Material On Site**												
X3.9	Some of the materials delivered did not meet specifications due to factory errors	5	11	7	5	2	30	5	10	8	5	2	30
X3.10	Some materials were not delivered due to factory errors	5	11	11	1	2	30	3	16	9	1	1	30
X3.11	Some of the materials delivered did not meet specifications due to factory errors	4	12	7	6	1	30	5	13	10	2	0	30

Table 8. Recapitulation of data from the results of the respondent's questionnaire in the implementation of the elevator installation

II. Implementation Of Elevator Installation													
Variable	Indicator	Probability (P)						Impact (I)					
		1	2	3	4	5	SUM	1	2	3	4	5	SUM
II.1.	**Preparation**												
X4.1	Delay in the work tools	2	15	10	2	1	30	3	15	5	5	2	30
X4.2	Delay delivery of tools to the project	3	12	10	3	2	30	5	13	6	4	2	30
X4.3	Stock of required safety and work tools is missing	3	15	6	4	2	30	3	14	7	4	2	30
X4.4	Power supply is not available	3	11	9	6	1	30	3	7	5	8	7	30
II.2.	**EHS Audit**												
X4.5	Pit, shaft, machine room and the area arround installation conditions are still potentially hazardous	1	10	9	6	4	30	2	11	6	5	6	30
X4.6	Installation of work and safety equipment is not standardized	6	13	7	3	1	30	6	16	3	2	3	30
II.3.	**Installation**												
X4.7	The dimension of hoistway, machine room and pit do not match the required dimensions	3	11	3	11	2	30	2	5	6	11	6	30
X4.8	Damage tools during installation elevator	3	11	8	8	0	30	5	12	8	5	0	30
X4.9	Placement of material in the crate does not match the list listed on the material crate	13	12	3	2	0	30	13	12	3	2	0	30
X4.10	Setting the plumb line template incorrectly	6	14	6	2	2	30	6	14	6	2	2	30
X4.11	Disputes with other contractors	4	13	6	5	2	30	4	13	6	5	2	30
X4.12	Material damage	2	14	8	3	3	30	1	8	11	8	2	30
X4.13	Rework	2	11	8	7	2	30	1	10	9	7	3	30
X4.14	Poor EHS management in the site	3	12	9	5	1	30	3	12	9	5	1	30
X4.15	Low quality of labor	3	11	9	3	4	30	1	6	9	10	4	30
X4.16	Lack of competent labor	1	10	11	7	1	30	0	8	12	7	3	30
X4.17	Low of labor motivation	7	8	9	3	3	30	4	5	12	6	3	30
X4.18	Low of labor productivity	5	11	8	4	2	30	3	9	10	6	2	30
X4.19	Labor dispute	14	6	7	3	0	30	12	8	6	4	0	30
X4.20	Non standard measuring tools	10	11	6	3	0	30	8	11	6	4	1	30
X4.21	Poor coordination within thee team	7	10	9	3	1	30	5	11	9	4	1	30
X4.22	Poor external coordination	5	11	8	6	0	30	4	12	7	5	2	30
X4.23	Loss of elevator material during installation	2	9	10	8	1	30	1	8	11	8	2	30
X4.24	Elevator electrical component problem	3	10	13	4	0	30	2	10	12	5	1	30
X4.25	New elevator system	6	10	13	1	0	30	7	7	12	4	0	30
X4.26	Delay in payment of work progress	2	7	10	8	3	30	2	6	10	9	3	30
X4.27	Delay in payment of workers wage	6	8	9	5	2	30	6	8	8	7	1	30
X4.28	Slow internal decision	7	10	7	5	1	30	4	12	11	3	0	30

	making												
X4.29	Late start of project implementation	4	13	7	6	0	30	3	8	12	6	1	30
X4.30	Poor supervision	4	15	7	3	1	30	5	9	9	5	2	30
X4.31	Too many projects being handled at the same time	1	6	14	7	2	30	1	7	13	7	2	30
X4.32	Delay delivery of materials to the project site	5	12	8	5	0	30	3	11	12	4	0	30
X4.33	Wrong survey	5	12	6	6	1	30	3	8	7	10	2	30
X4.34	Incorrect method	11	10	7	2	0	30	7	8	8	7	0	30
II.4.	**Quality Check**												
X4.35	QC check are carried out repeatedly	1	12	6	10	1	30	3	8	11	6	2	30
II.5.	**Test and Commissioning**												
X4.37	Recurring checklist with the owner	4	11	8	6	1	30	4	11	8	6	1	30
X4.38	Several elevator components were damaged and not active during test and commissioning	6	13	7	4	0	30	4	16	4	6	0	30
II.6.	**Handover of the unit to the owner**												
X4.39	Supporting documents for the handover process are incomplete	6	11	7	6	0	30	7	12	6	5	0	30

Validity and Reliability Test

After stage 2 was carried out, the validity and reliability tests of each risk factor were carried out. The results of the validity test show that of the 11 risk factors in the implementation of the elevator procurement, all of them have a value of R Count > R Table (R Table = 0.374) for the probability scale and impact scale so that all risk factors are valid. As for the 38 risk factors in the implementation of the elevator installation, there were 4 factors that were invalid and were excluded because they had an R count < R Table (R Table = 0.374). 4 risk factors are X4.1. has an R Count of 0.250 for the probability scale and 0.292 for the impact scale, X4.2. has an R Count of 0.306 for the impact scale, X4.3. has an R Count of 0.337 for the impact scale and X4.5 has an R Count value of 0.344 for the probability scale.

The reliability test from risk factors shows that the Cronbach-alpha scored 0,923 for elevator procurement implementation probability and scored 0,931 for the impact scale. While the reliability test for the probability scale in the implementation of elevator installation scored 0,946 and the impact scale scored 0,952. Since both of the risk factors show reliability scores > 0,6 then it is said that the risk factors were reliable.

Hypothesis Testing

After the validity and reliability tests, the next statistical test performed to prove the hypothesis is the Kruskal-Wallis test. Which aims to test the effect of level of education, work experience and position on respondents' responses regarding risks factors.

Effect of Respondents' Education level

The first hypothesis testing, is to test the impact of education on respondents' perceptions of the probability scale and impact scale in the implementation of the elevator procurement and installation, ranging from high school, diplomas, bachelor and master's degree.

The results of testing the effect of education level on respondents' perceptions for the probability scale and impact scale in the implementation of the elevator procurement show that the p-value (Asymp.Sig) > 0.05, which means that Ho is acceptable or there is no difference in perceptions at the education level of the respondents'.

The results of testing the effect of education level on respondents' perceptions for the probability scale and the impact scale in the implementation of the elevator installation obtained p-value (Asymp.Sig) > 0.05, except for the variables X4.32, X4.35 and X4.39 for the probability scale have a p-value (Asymp.Sig) < 0.05. The variable X4.32 has a p-value (asymp.sig) of 0.019, X4.35 has a p-value (asymp.sig) of 0.016 and X4.39 has a p-value (asymp.sig)of 0.038. So Ho is accepted except for the variables X4.32, X4.35 and X4.39. In this case there is no difference in respondents' perceptions based on the level of education of the respondents, except for variables X4.32, X4.35 and X4.39 on the probability scale. thus the variables X4.32, X4.35, and X4.39 are rejected and removed from the list of risk variables.

Effect of Respondents' Work Experience

Next is to test the effect of work experience on respondents' perceptions of the probability and impact scale in the implementation of elevator procurement and installation, ranging from under 10 years to over 20 years.

The results of testing the effect of work experience on respondents' perceptions for the probability scale and the impact scale in the implementation of the elevator procurement obtained p-value (Asymp.Sig) > 0.05, except for variable X3.9 has a p-value (Asymp. Sig) < 0.05 on the probability scale. The variable X3.9 has a p-value (Asymp. Sig) of 0.037. Thus Ho is accepted or there is no difference in perception based on the work experience of the respondents. except variable X3.9. Therefore variable X3.9 is rejected and removed from the list of risk variables.

The results of testing the effect of work experience on respondents' perceptions for the probability scale and the impact scale in the implementation of the elevator installation obtained p-value (Asymp.Sig) > 0.05, except for variable X4.34 has a p-value (Asymp. Sig) < 0.05 on the impact scale. The variable X4.34 has a p-value (Asymp. Sig) of 0.036. Thus Ho is accepted or there is no difference in perception based on the work experience of the respondents. except variable X4.34. Therefore variable X4.34 is rejected and removed from the list of risk variables.

Effect Of Respondents' Position

The last hypothesis testing is to test the effect of position on respondents' perceptions for probability and impact scales in the implementation of elevator procurement and installation. The position ranging from site mechanic leader, site manager, project engineer and project manager.

The results of testing the effect of position on respondents' perceptions for the probability and the impact scale in the implementation of the elevator procurement obtained p-value (Asymp.Sig) > 0.05, except for variable X3.5, X3.7, and X3.8 have a p-value (Asymp. Sig) < 0.05 on the impact scale. The variable X3.5 has a p-value (Asymp. Sig) of 0.027, X3.7 has a p-value (Asymp. Sig) of 0.032, and X3.8 has a p-value (Asymp. Sig) of 0.030 . Thus Ho is accepted or there is no difference in perception based on the position of the respondents, except variables X3.5, X3.7, and X3.8. Therefore variables X3.5, X3.7 and X3.8 are rejected and removed from the list of risk variables.

Based on the results of testing the effect of position on respondents' perceptions on the probability and impact scale in the implementation of the elevator installation obtained the p-value (Asymp. Sig) > 0.05. Thus Ho is accepted or there is no difference in perception based on the position of the respondents

Risk Analysis

The risk analysis used is risk analysis based on PMBOK 2017. Risk analysis is carried out on variables that have passed each statistical test that was carried out previously. Risk analysis is carried out by finding the average probability value by multiplying the number of respondents' answers on each probability scale with the value of the probability scale and then adding them up. After the probability value is obtained, then the probability value is divided by the number of respondents to obtain the average probability value. The same thing was done to find the average impact value. Then to obtain the risk value (R) the average probability value (P) is multiplied by the average impact value (I). Then to obtain the risk value (R) the average probability value (P) is multiplied by the average impact value (I). After the risk value is obtained, then each risk variable is given a risk rating based on the risk value in each variable. The risk rating results of the risk variables involved in procuring and installing elevators can be seen in Table 9 and Table 10.

Table 9. Risk Rating On The Elevator Procurement Process

Variable	Probability Average Value (P)	Impact Average Value (I)	Risk Value (R = P x I)	Risk Rating
X3.1	0,427	0,293	0,125	2
X3.2	0,400	0,253	0,101	4
X3.3	0,380	0,282	0,107	3
X3.4	0,493	0,412	0,203	1
X3.6	0,333	0,235	0,078	5
X3.10	0,393	0,158	0,062	6
X3.11	0,420	0,145	0,061	7

Table 10. Risk Rating On The Elevator Installation Process

Variable	Probability Average Value (P)	Impact Average Value (I)	Risk Value (R = P x I)	Risk Rating
X4.4	0,440	0,355	0,156	2
X4.6	0,367	0,190	0,070	22
X4.7	0,487	0,367	0,178	1
X4.8	0,440	0,168	0,074	21
X4.9	0,260	0,108	0,028	30
X4.10	0,367	0,177	0,065	24
X4.11	0,420	0,210	0,088	14
X4.12	0,440	0,262	0,115	9
X4.13	0,473	0,268	0,127	7
X4.14	0,427	0,198	0,085	19
X4.15	0,460	0,322	0,148	4

X4.16	0,480	0,280	0,134	5
X4.17	0,413	0,263	0,109	10
X4.18	0,413	0,235	0,097	12
X4.19	0,293	0,140	0,041	29
X4.20	0,313	0,170	0,053	28
X4.21	0,373	0,185	0,069	23
X4.22	0,400	0,213	0,085	18
X4.23	0,480	0,262	0,126	8
X4.24	0,420	0,210	0,088	15
X4.25	0,360	0,168	0,061	26
X4.26	0,520	0,290	0,151	3
X4.27	0,427	0,210	0,090	13
X4.28	0,387	0,160	0,062	25
X4.29	0,400	0,218	0,087	16
X4.30	0,380	0,218	0,083	20
X4.31	0,520	0,258	0,134	6
X4.33	0,407	0,265	0,108	11
X4.37	0,427	0,203	0,087	17
X4.38	0,360	0,167	0,060	27

Risk Level

The risk level analysis is a mapping of risk values into a probability and impact matrix (PMBOK, 2017). After the mapping of each variable into the probability and impact matrix, the risk level will then be determined.

The results of the risk classification into the probability and impact matrix and the risk level of each risk variable with a medium level risk in the implementation of lift procurement and installation are shown in the following table 11 and table 12.

Table 11. Risk Level of Elevator Procurement Process

Variable	Risk Value (R = P x I)	Risk Rating	Risk Level
X3.4	0,203	1	Medium
X3.1	0,125	2	Medium
X3.3	0,107	3	Medium
X3.2	0,101	4	Medium
X3.6	0,078	5	Low
X3.10	0,062	6	Low
X3.11	0,061	7	Low

Table 12. Risk Level of Elevator Installation Process

Variable	Risk Value (R = P x I)	Risk Rating	Risk Level
X4.7	0,178	1	Medium
X4.4	0,156	2	Medium
X4.26	0,151	3	Medium
X4.15	0,148	4	Medium
X4.16	0,134	5	Medium
X4.31	0,134	6	Medium
X4.13	0,127	7	Medium
X4.23	0,126	8	Medium
X4.12	0,115	9	Medium
X4.17	0,109	10	Medium
X4.33	0,108	11	Medium
X4.18	0,097	12	Medium
X4.27	0,090	13	Medium
X4.11	0,088	14	Medium
X4.24	0,088	15	Medium
X4.29	0,087	16	Medium
X4.37	0,087	17	Medium
X4.22	0,085	18	Medium
X4.14	0,085	19	Medium
X4.30	0,083	20	Medium
X4.8	0,074	21	Low
X4.6	0,070	22	Low

X4.21	0,069	23	Low
X4.10	0,065	24	Low
X4.28	0,062	25	Low
X4.25	0,061	26	Low
X4.38	0,060	27	Low
X4.20	0,053	28	Low
X4.19	0,041	29	Low
X4.9	0,028	30	Low

IV. FINDINGS AND DISCUSSION

Based on expert validation of the implementation of the procurement and installation of elevators, obtained the guidelines for the implementation of the procurement and installation of elevators were obtained, namely:

1. Guidelines For Procurement Of Elevators
   The guideline for the procurement of elevators are divided into 4 stages
   - The negotiation stage consists of defining detailed elevator specifications, making sales proposals and making layout drawings.
   - Proposal approval stage and contract award by the owner
   - ordering stage consists of making design drawings for production, approval the elevator design by the owner, sending elevator specifications to be produced to the factory and ordering elevators by the E-log team
   - Elevator fabrication stage by elevator factory
   - Elevator delivery stage from factory to project site (MOS)
2. Guidelines For Installation Of Elevator
   The guidelines for installing elevators are divided into 6 stages
   - Preparation consists of making work methods, coordinating the availability of electric power for installing elevators, making installation schedules, planning work equipment, planning installation teams, installing work equipment and pre-start checklists for the condition of the hoistway, machine room and the area around hoistway and handover of the hoistway.
   - EHS audit consists of making an audit request to the EHS team and pre-installation inspection with the EHS team
   - The installation consists of setting the plumb line template, installing the rail stage 1, installing the elevator cage, installing the device in machine room, installing the working platform, installing the cwt frame, rope and filler weight, installing the traveling cable, tension and rope governor, low speed by adjuster, installimg the rail stage 2, installation of hoistway doors, installation of hoistway and pit devices, high speed and safety test processes, installation of interphones and hall buttons.
   - The quality inspection consists of request for quality check to QC department and quality check by QC department
   - Test and commissioning
   - Elevator handover to owner

Based on the results of the risk analysis in the implementation of the procurement of elevators in table 11 and the implementation of the installation of elevators in table 12, the risk factors obtained are risk factors with medium and low levels. No high level risk factors were found in this study. This happened because most respondents chose answers at medium and low levels both on the probability scale and the impact scale. This can be seen in the results of the recapitulation of the respondents' questionnaire answers in table 7 for the procurement of elevators and table 8 for the installation of elevators so that when the risk assessment is carried out, the risk values obtained are at medium and low levels. In table 7 for the procurement of elevators, it can be seen the risk factors such as the scope of work in the contract is not clear (X3.4), and some of the materials delivered did not meet specifications (X3.2), although most respondents chose a very high level on the impact scale but on the other hand most respondents chose low and medium levels on the scale probability. This shows that respondents think that the possibility of these risk factors only occurs in certain conditions or rarely occurs, but if it occurs, the impact will be very high. So that when the risk assessment is carried out, the risk value obtained is at a medium level. In table 8 for the installation of elevators, it can be seen the risk factors such as the dimension of hoistway, machine room and pit do not match the required dimensions (X4.7), low quality of labor (X4.15), and wrong survey (X4.33) although most respondents chose a very high level on the impact scale but on the other hand most respondents chose low and medium levels on the scale probability. This shows that respondents think that the possibility of these risk factors only occurs in certain conditions or rarely occurs, but if it occurs, the impact will be very high. So that when the risk assessment is carried out, the risk value obtained is at a medium level.

For medium risk level, it is necessary to carry out risk mitigation to reduce the probability of occurrence and impact of a risk (PMBOK 2017), so that the risks analyzed in this study are risk factors with a medium level. In this study, 4 risks with a medium level were obtained in the implementation of the elevator procurement such as the scope of work in the contract is not clear (X3.4), lack of information on design requirements (X3.1), some materials were not delivered due to sales errors (X3.3), and some of the materials delivered did not meet specifications due to sales errors (X3.2). These findings confirm the results of Azambuja et al (2006) research which identified problems in the implementation of elevator procurement and affected the elevator installation completion time, namely lack of information about design requirments and incomplete or incorrect orders are sent to the manufacturer resulting in incomplete lift materials being delivered and materials out of specification. In this study also obtained 20 risk factors with a medium level in the implementation of the elevator installation. The dimensions of hoistway, LMR and pit do not match the required dimensions (X4.7) and power supply is not available (X4.4) this finding confirm the results of Azambuja (2002). Low quality of labor (X4.15), rework (X4.13), loss of elevator material during installation (X4.23), poor supervision (X4.30) this finding confirm the results of Vieira et al (2021) which identified the main problems in elevator installation, namely the low qualification of the installation team, replacing materials that were lost and those that did not meet specifications took too long, and various installation quality problems which resulted in rework. Lack of competent labor (X4.16) and poor external coordination (X4.22) this finding is in line with Fathoni's research (2020) which states that lack of competent labor and poor external coordination are risk factors at a mrdium level. Delay in payment of work progress (X4.26), too many projects being handled at the same time (X4.31), material damage (X4.12), low of labor motivation (X4.17). wrong survey (X4.33), low of labor productivity (X4.18), delay in payment of workers wage (X4.27), disputes with other contractors (X4.11), elevator electrical component problem (X4.24), late start of project implementation (X4.29), recurring checklist with the owner (X4.37), poor EHS management in the site (X4.14).

Overall, from the results of the risk level analysis, the highest risk factors obtained in this study are risk factors with a moderate level. Most respondents believed that in reality these risk factors only occur under certain conditions and if these risk factors occur they will also have a medium impact.

IV. CONCLUSION

This research aims to analyze the dominant risk factors that influence the procurement and installation process of elevators in PT X which affect the performance of elevator installation time. Risk analysis is carried out based on PMBOK 2017, by using the concept of probability and impact matrix. From the results of the risk analysis carried out based on PMBOK 2017 which affects the performance of elevator installation time, the following result was found:

1. There are 4 dominant risk factors with a medium risk level in the implementation of elevator procurement in PT. X, namely the scope of the contract is not clear is the highest risk factor at the stage approval of proposals and award of contracts by the owner, Then lack of information about design requirements, some materials are not delivered and some materials sent are not in accordance with specifications are the risk factors at the negotiation stage.
2. There are 20 dominant risk factors with a medium risk level in the implementation of elevator installation in PT. X, namely power supply is not available (X4.4) is the risk factor at the preparation stage. The dimensions of hoistway, LMR and pit do not match the required dimensions (X4.7) is the highest risk factor at the installation stage, then other risk factors at the installation stage namely delay in payment of work progress (X4.26), low quality of labor (X4.15), lack of competent labor (X4.16), too many projects being handled at the same time (X4.31), rework (X4.13), loss of elevator material during installation (X4.23), material damage (X4.12), low of labor motivation (X4.17), wrong survey (X4.33), low of labor productivity (X4.18), delay in payment of workers wage (X4.27), disputes with other contractors (X4.11), elevator electrical component problem (X4.24), late start of project implementation (X4.29), poor external coordination (X4.22), poor EHS management in the site (X4.14), and poor supervision (X4.30). Recurring checklist with the owner (X4.37) is the risk factor at the test and commissioning stage.
3. In the process of procurement elevators, no risk factors were found with a medium level at the booking stage, fabrication stage and material on site stage.
4. In the process of elevator installation, no risk factors were found with a medium level at the EHS audit stage, qulity check stage and handover the unit to the owner stage.

V. RECOMMENDATION

Based on the results stated in the conclusion above, some suggestions are given in this study.

1. In order to minimize the risk factors that occur during the implementation of elevator procurement and installation and that affect time performance, it is necessary to consider and prepare a risk response plan. This involves looking at the causes and effects of each risk, and then determining preventive actions before the risk occurs, and determining corrective actions after the risk has occurred.
2. After the risk has been addressed, it is necessary to monitor the risk to ensure that the planned preventive and corrective actions can be properly implemented. planned preventive and corrective actions can be properly implemented.

REFERENCES

Azambuja, M. M. B., Isatto, E. L., Marder, T. S., & Formoso, C. T. (2006). The importance of commitments management to the integration of make to order supply chains in construction industry. Proceedings IGLC-14, July 2006, Santiago, Chile, 809 – 623. https://www.researchgate.net/publication/242354261

Heikilla, T. (2009). General description of Marine elevator installation process, with focus in improving door installation method. Hannover (2009). (Company, 2012)

Martinelli, R. J., Milosevic, D. Z. (2016). Project Management Toolbox Second Edition. New Jersey : John Wiley & Sons, Inc. Indonesia.

PMI. (2017). (PMI, 2017). In PMBOK Guide.

Pritchard, C. L. (2015). Risk Management Concepts and Guidance Fifth Edition. Boca Raton : Taylor & Francis Group, LLC.

Suwankanit, T. (2019). The identification of failure modes in the elevator installation process of a case company in Thailand by FMEA. London Journals of Engineering Research, 19(4), 21 – 28. http://creativecommons .org/licenses/by-nc/4.0/)

Vieira, G. F., & Weiss, J. M. G. (2021). Applications of template A3 and value-stream mapping in process improvement: the case of building elevators installation. Gestão & Produção, 28(1), e4795. https://doi.org/10.1590/1806-9649.2020v28e4795

Yaman, O., Baygin, M., & Karakose, M. (2016). A new approach based on image processing for detection of wear of guide rail surface in elevator systems. International Confrence on Advanced Technology and Sciences (ICAT'16), September 2016, Konya, Turkey, 181 – 186.

Shukla, V. V., & Tambe, P. P. (2018). Decision factors in the selection of *elevator*. *i-manager's Journal on Mechanical Engineering, 8(2), 42 – 51.*

Wideman, R. M. (1992). Project & Program Risk Management (A Guide To Managing Project Risks & Opportinities). Pennsylvania : Project Management Institute, Inc.

Indonesia. Regulation of the Minister of Labor of the Republic of Indonesia Number 6 of 2017 concerning Work Safety and Health of Elevators and Escalators. State Gazette of the Republic of Indonesia No. 909 of 2017.

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