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Project Management Analysis of Manufacturing Laboratory Development by Considering Risk Factors

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A B S T R A C T

Laboratory construction project is a project owned by the University of XYZ Madiun. Laboratory construction has the goal of adding practice facilities to the industrial engineering department. Laboratory construction supports the offline learning process when students do practice activities. This project was carried out by PT ABC with a project value of Rp. 500.000.000. PT ABC was selected through an appointment stage by the project owner without a tender process. Laboratory construction process was built for 12 weeks. Laboratory construction process was built from early June 2021 until the end of August 2021. Manufacturing laboratory projects require a review of project management and risk management in their implementation so that project work can avoid delays in time. Project management analysis shows that the critical track is the activity of A-C-F-G with a total duration of 84 days and the probability of the project being completed is 96.16%. The calculation of the average profit obtained by project implementers is Rp 59.893.125. Risk management measurements show that high category risks are erratic weather, poor safety regulations in the field, and low levels of management discipline.

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1. Introduction

Laboratories provide a vital role in the learning process within the scope of the college. The learning process requires a theoretical test through practical activities. Practice has four benefits, including cognitive studies, design studies, social studies, and professional studies (Sulthoni, 2021). Support for practical activities by students requires a large number of laboratories. Fulfillment of the number of laboratories is part of the standard of learning infrastructure (PerMenDikBud No. 3, 2020). Infrastructure in the laboratory supports undergraduate education in the industrial era 4.0 (Coşkun et al., 2019). The situation of online-based education when the COVID-19 pandemic requires practicum activities to be carried out directly (Nandana & de Mel, 2016).

The laboratory requires attention related to units' addition in accordance with learning curriculum development and science scope. Manufacturing laboratory is one of the additional laboratories used in supporting science in Industrial Engineering Department at University of XYZ Madiun. Construction process is shown in Figure 1. construction process was carried out for 3 months, starting from June 1, 2021 to September 30, 2021.

Figure 1. Manufacturing Laboratory Construction Process

Laboratory construction stages require planning through project management studies. Project management analysis contributes to cost and time so that the project can be executed according to plan (Azizah et al., 2020). The project plan suitability needs supervisory support while the project is being worked on (Wospoga et al., 2015). The project pace doesn't always run smoothly, so early detection warning actions need to be considered (Permatasari et al., 2015). Benchmarks of early detection success through complex scheduling are possible, but it requires optimal expertise, time and energy (Yulianto, 2013). Projects are often late due to scheduling factors that have not undergone periodic updates with conditions in the field. Updating information related to inter-employment relationships shows a critical trajectory that makes it easier to optimalise in the case of work delays (Maulidi et al., 2021).

During the 3-month work, the manufacturing laboratory construction project was delayed. Project delays affect the time of use of laboratories in student practice activities. Ineffective project control effects uncontrolled costs (Iswati et al., 2017). Project delays will have an impact not only on costs but also on consumers' views of the project implementers' credibility (Abdurrasyid et al., 2019). Factors causing project delays include weather disruption, material procurement, work equipment, and labor empowerment (Asnuddin et al., 2018). Some changes to the time schedule, project drawing, and effectiveness in the work implementation also affect the potential delays that occur (Hadi & Anwar, 2018).

The manufacturing laboratory construction process also has an impact on Safety, Occupational, Health, and Environmental Management System. The development project's impact contributed to the highest accident, which was 31.9% of the total accidents that occurred (Bayu Dharma et al., 2017). The work accident numbers from year to year have increased by about 5% – 10% (Nugroho et al., 2018). Work accidents can occur due to two things: namely, humans who do not meet work safety requirements and an unsafe environment (Wisudawati & Patradhiani, 2020). Environmental impacts due to development projects can be soil contamination or pollution, noise, licensing, public opinion, internal policies, environmental regulations, or environmental impact requirements (Ismiyati et al., 2020).

The project problems are not necessarily influenced by external factors, but more often due to internal factors. Internal factors can be from the labor sector involved in the development project. Skill shortages and worker turnover can result in low labor productivity (Messah et al., 2013). Unprofessionalism in the labor selection resulted in a long time lag in completing the project. Conflicts of interest can affect the quality and quality of laboratory construction projects (Armaeni, 2014). Conflicts of interest in the manufacturing laboratories' construction include no auction and only the implementing contractor's appointment, resulting in the project owner, Industrial Engineering, University of XYZ Madiun, not having options in the laboratory quality terms. These problems have a direct impact on construction business ethics violations (Kirana, 1996).

Based on the above problems, the laboratory construction project is carried out to the problems' impact. The laboratory development project's impact evaluation is an alternative solution for future improvements to laboratory construction at the University of XYZ Madiun. Good laboratory quality can provide an increase in the knowledge transfer achievement between lecturers and students in the practical activity process.

2. Literature Review

2.1 Project Management

Project management is a review in project control. The project control process needs to be planned in a structured manner. The best steps in planning are through the activities management, such as project scheduling and human resource management that are directly involved in a project so that it will lead to an estimated project cost that needs to be budgeted by a company (Arianie & Puspitasari, 2017). Although planning has been done, delays and long time durations can still occur (Larasati & Sutopo, 2020). Other issues that may emerge gradually in the project include a lack of coordination between construction management and contractors, delays in material arrival, or labor amounts that are insufficient for the project's capacity (Tama et al., 2020).

Project management is necessary because the project has certain characteristics that are different from other activities in organization terms: management, resource use, time, complexity, and uncertainty (Santosa, 2009). Certain ways of handling different project constraints are needed through handling other activities. Constraints that affect each other are commonly referred to as the "triangle of project constraints," namely the scope of work (scope), time, and cost. Figure 2 shows project constraints. The three trains' balance will determine the project's quality. Changes in one or more of these factors will affect at least one other factor (PMI, 2021).

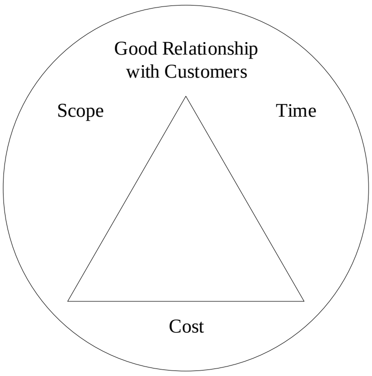

Figure 2. Limitations in Project Execution

2.2 Risk Management

The Safety, Occupational, Health, and Environmental Management System is the company's system part that includes planning to make decisions on the organization's and managerial aspects as a whole and cannot be separated from the work environment. This management system has the basis of extracting facts on operational aspects that result in work accidents (Pesa & Taufik, 2017). Risk events in construction projects can be managed through risk management. Risk management activities are often overlooked in projects, but they can help improve project success through initiation, project scope, and developing realistic forecasts (Salimah et al., 2019). The risk management steps are generally carried out through three stages, namely risk identification, risk assessment, and risk mitigation (Fahlevi et al., 2019). Further explanation of the risk management process is as follows :

1) Risk identification

   Risk identification, according to Gray & Larson (2007), is a project analysis to identify the risk source. The risk management process begins by attempting to generate a list of all the risks that may affect the project. One common mistake in the initial process of risk identification is focusing on consequences rather than events that can produce consequences.

2) Risk assessment

Risk assessment is carried out to determine the dimensions, size, or weight in relation to the risk type, the impact it causes, and the possibility of such risks (Soeharto, 2002). One method of risk assessment is risk matrix. Risk matrix method is measured based on occurance and severity values. Each occurance and severity value of each risk are plotted where the x axis is severity level and the y axis is occurance level (Yuliani, 2017). The list of occurance and severity values can be seen in Table 1 and Table 2. (AS/NZS, 2004). Visualization results of the risk matrix form can be seen in Figure 3 (Kusuma, 2019). Risk Priority Number (RPN) value can be obtained through the multiplication of occurrence and severity with color addition according to risk category.

3) Risk mitigation

Risk mitigation is a process, technique, or strategy to overcome risks that may arise. This risk mitigation can be grouped (Gray & Larson, 2007) as reduction, avoidance, displacement, sharing, or retention. Risk mitigation is also a procedure to increase understanding and awareness among personnel in the organization concerned (Soeharto, 2002).

Table 1. Tingkat Kemungkinan Terjadinya Suatu Risiko / *Occurance*

Level	Description	Explanation
5	Almost Certain (A)	It can happen at any time
4	Likely (L)	Often
3	Possible (P)	It can happen once in a while
2	Unlikely (U)	Infrequently
1	Rare (R)	Almost never or very rarely

Table 2. Tingkat Keparahan Suatu Risiko / *Severity*

Level	Description	Explanation
1	Insignificant (I)	No injuries, little financial loss.
2	Minor (Mi)	Minor injuries, moderate financial loss.
3	Moderate (Mo)	Moderate injury, medical treatment required, significant financial loss.
4	Major (Ma)	Severe injuries to more than one person, significant losses, and project disruption.
5	Catastrophic (C)	Loss is significant, and the impact is far-reaching; the loss is caused by the cessation of all activities.

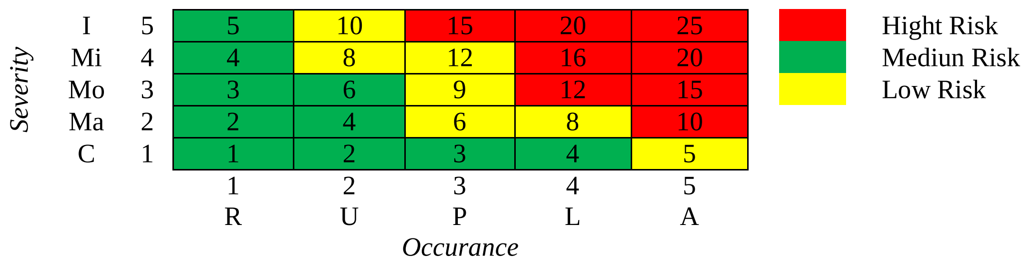

Figure 3. An Example of A Risk Matrix Chart

3. Reseach Method

The construction site for the manufacturing laboratory is located on Marga Tama Street, within the Laboratorium Terpadu Complex. The development area occupies the GOR Cendekia parking lot. The project location can be seen in Figure 4. The manufacturing laboratory construction is divided into 11 work stages, including preparation, excavation & foundation, concrete, installation & plastering, roof, platfond, floor & wall covering, door & window, water installation, painting and electrical. The project work schedule starts from the first week of June 2021 until the last week of August 2021. Figure 5 is a schedule of the working time for each of the activities on the manufacturing laboratory construction project. The construction time for the construction project is 12 weeks. The duration of work time each week is six working days.

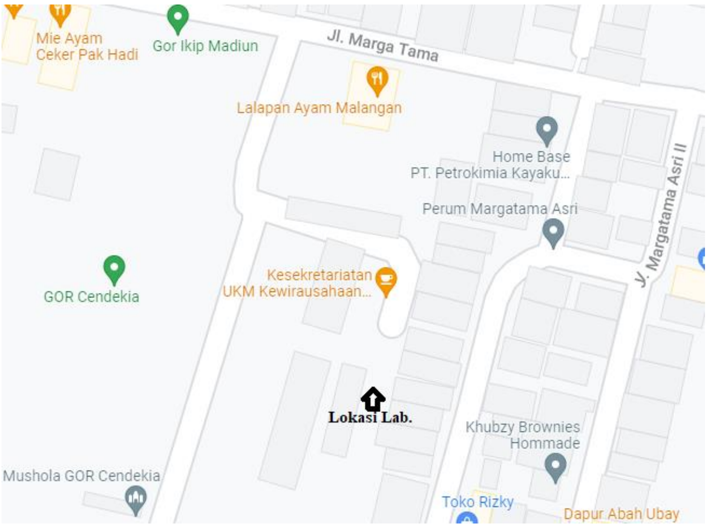

Figure 4. Location of Manufacturing Laboratory Construction

Job description	June				July				August			
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12
Preparation Work (A)												
Excavation & Foundation Work (B)												
Concrete Work (C)												
Installation & Plastering Work (D)												
Roof Work (E)												
Platfond Work (F)												
Floor & Wall Covering Work (G)												
Door & Window Work (H)												
Water Installation Work (I)												
Painting Work (J)												
Electrical Work (K)												

Figure 5. Project Activity Schedule

Figure 6 shows the research steps. This research begins with field studies and literature studies. Field studies and literature studies are conducted to learn from the scope of project management theory as well as the risk of spoiling that is a problem in this research. The problem was later identified. The problem identification activity is to review so that the problem is known to be questioned. The problem's identified result becomes a reference in data collection. Data collection is divided into primary data (measurement results) and secondary data (empirical data retrieval results). Data collection results are input for data processing related to risk management and project management issues. Data processing related to project management includes activity network creation, Critical Path Method (CPM) calculation, Program Evaluation and Review Technique (PERT) calculation, and project cost analysis. Data processing related to risk management includes risk identification, risk assessment, and risk response development. Data processing results related to project management and risk management become evaluation materials in the conclusion drawing.

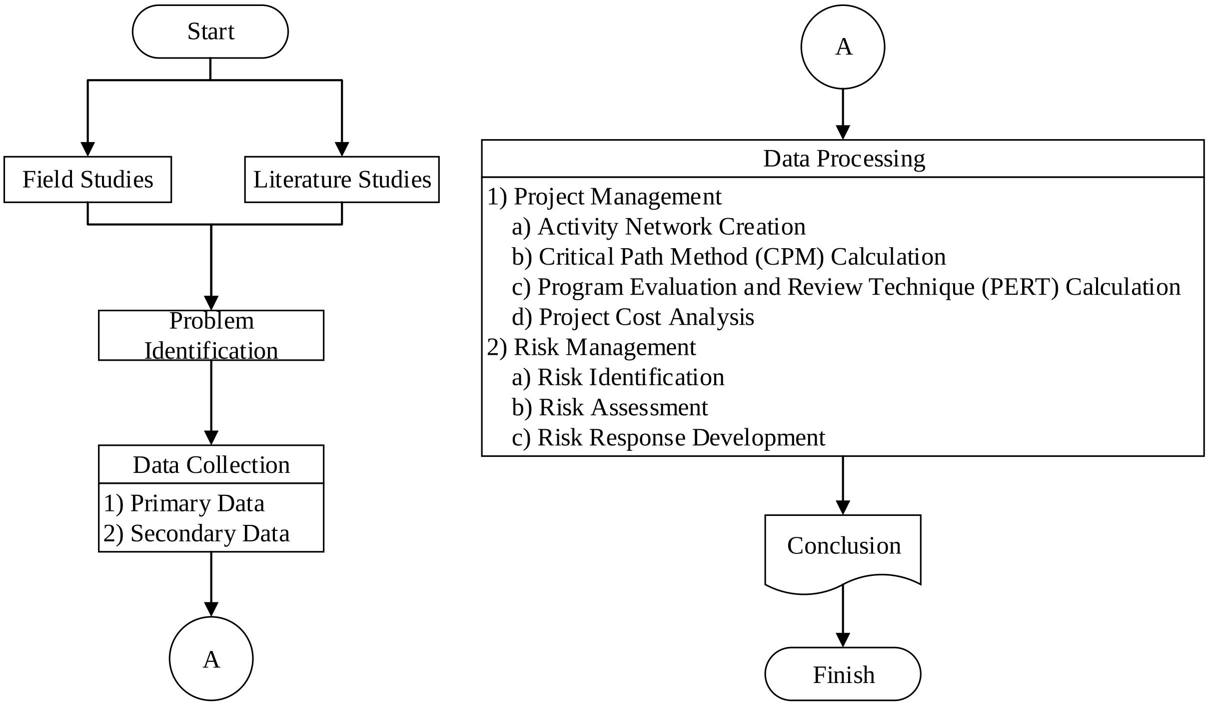

Figure 6. Research Steps

4. Results and Discussion

Every activity in the manufacturing laboratory construction process has a duration for its activities. Table 3 shows activity with a project activity predensesor. The identification results of activity time on development projects are made into work networks using PDM. Work network results for the manufacturing laboratory construction project can be seen in Figure 7. Work network facilitates understanding of the relationships between project activities. Time calculations include Early Start (ES), Early Finish (EF), Late Start (LS), Late Finish (LF) and slack. CPM calculations can be seen in Table 4. The critical line result from the CPM method is A–C–F–G, with a total duration of up to 84 days.

Table 3. Project Activity Predecessor

Code	Activity Description	Day Number	Predensesor
A	Preparation Work	6	-
B	Excavation & Foundation Work	12	-
C	Concrete Work	30	A
D	Installation & Plastering Work	30	B
E	Roof Work	12	C
F	Platfond Work	12	E
G	Floor & Wall Covering Work	24	F
H	Door & Window Work	12	F
I	Water Installation Work	24	A
J	Painting Work	6	H
K	Electrical Work	18	C

Critical line results need to be controlled during the project being worked on. Project control can reduce delays and coordinate various work actions so that the project can be completed on time. The manufacturing laboratory construction project is also analysed by the PERT method. The PERTmethod results can be seen in Table 5. If the z result value is 1.77, then the project's probability of being completed is 96.16%. Cost calculations are based on activities in the project by looking at daily progress for 12 weeks. Figure 8 shows the relationship between actual cost, earned value, and planned value. The graph results show that the project ran on time and gave a profit margin of Rp

19.675.000 in the 12th week. Table 6 shows Cost Variance (CV), Schedule Variance (SV), Cost Performance Index (CPI), Schedule Performance Index (SPI), and Estimated Cost at Completion (EAC). CV and SV show positive results, indicating that the workmanship progress at all times does not experience obstacles in its implementation.

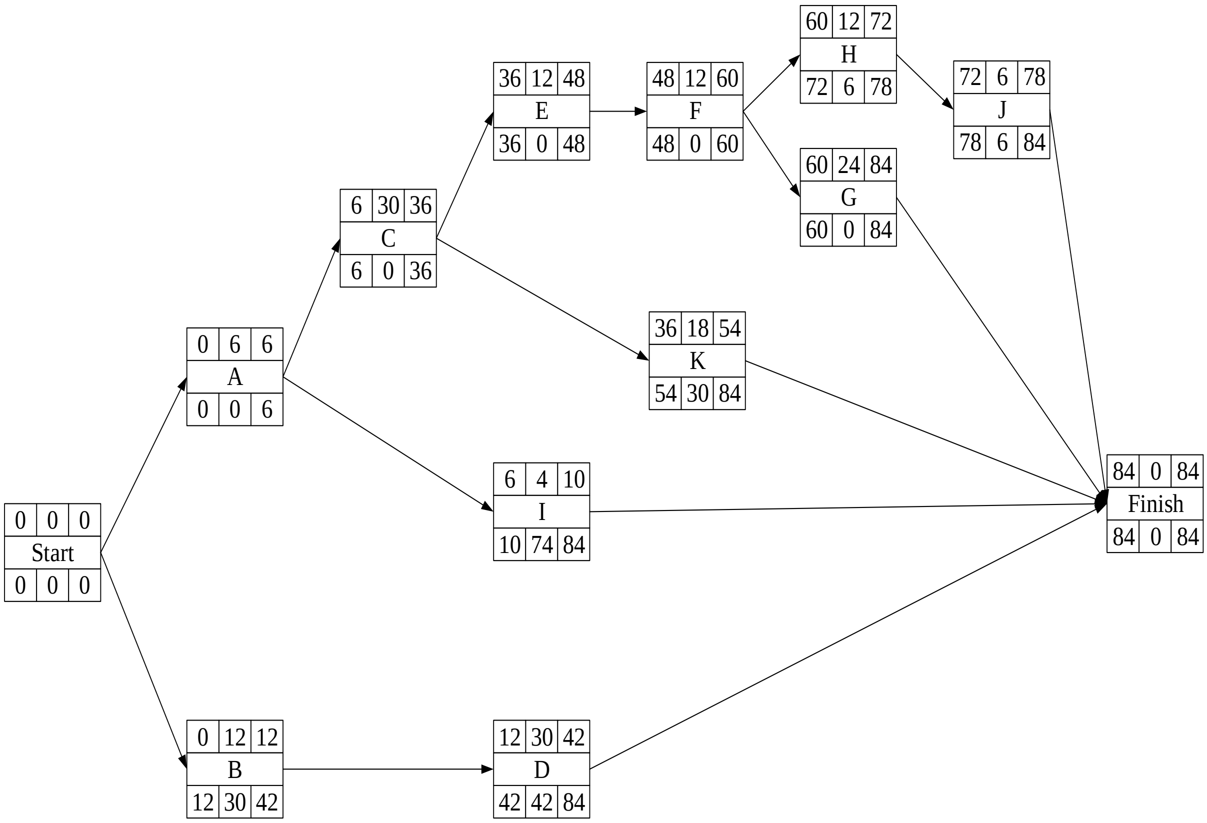

Figure 7. Project Activity Network

Table 4. CPM Calculation

Code	Activity Description	Day Number	Predensesor	ES	EF	LS	LF	Slack
A	Preparation Work	6	-	0	6	0	6	0
B	Excavation & Foundation Work	12	-	0	12	12	42	30
…	…	…	…	…	…	…	…	…
J	Painting Work	6	H	72	78	78	84	6
K	Electrical Work	18	C	36	54	54	84	30

Table 5. PERT Calculation

Code	Optimistic Time (t_o)	Realistic Time (t_m)	Pessimistic Time (t_p)	*Expected Time* $T = (t_o + 4t_m + t_p)/6$	Variance $[(b-a)/6]^2$
A	5	6	7	6	0.11
B	10	12	13	11.83	0.25
…	…	…	…	…	…
J	5	6	7	6	0.11
K	17	18	19	18	0.11

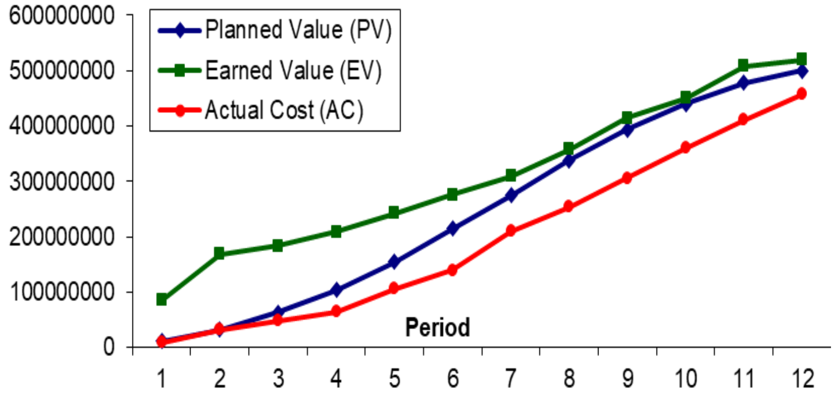

Figure 8. PV, EV and AC Relationship Graph

Table 6. CV, SV, CPI, SPI and EAC Calculation Results

Week	CV	SV	CPI	SPI	EAC
1	Rp. 76.565.000	Rp. 73.655.000	9,56	7,22	Rp. 52.277.645
2	Rp. 136.272.500	Rp. 136.470.000	5,23	5,26	Rp. 95.678.554
…	…	…	…	…	…
11	Rp. 96.880.000	Rp. 29.437.500	1,24	1,06	Rp. 404.662.091
12	Rp. 61.992.500	Rp. 19.675.000	1,14	1,04	Rp. 440.354.549

The stages of risk management analysis in this research are risk identification, risk assessment, and risk evaluation. The risk analysis process was carried out from June 1, 2021, to August 4, 2021. The sources in this research are all involved in the laboratory construction project, such as project managers, chief executives, supervisors, staff, handymen, and porters. The risk identification process is carried out by observation in the field and using a preliminary questionnaire tool. The preliminary questionnaire helps if there is a data lack when observations in the field are insufficient. The risk identification results can be seen in Table 7. Seven risk agents and 30 sub-risks are aware of the risk identification results.

Table 7. Risk Identification Results

Checklist		Hazard
Force Majeure	1	Fire
	2	Bad weather
Materials and Equipment	3	Material price increase
	4	Late material ordering
	…	…
	8	Lack of material landfills
	9	Material delivery volume is not right
…	…	…
Construction	15	Design changes
	16	Incomplete design data
	17	Error in time estimation
	18	safety regulations not being implemented in the field
	19	Improper concrete testing
…	…	…
Implementation	26	The presence of hazardous waste is caused by the project
	27	Residents around the project site were disrupted
	…	…
	29	Changes in work implementation schedule
	30	Damage during the maintenance period

Sub-risk results from risk identification become evaluated as risk assessments. The risk assessment process uses a closed questionnaire tool. Figure 9 shows a risk assessment diagram. Risk assessment of manufacturing laboratory construction projects uses the risk matrix method. The risk matrix method helps groups based on their occurrence and severity. The risk assessment results are known to have four sub-risks in the high risk category, seven sub-risks fall into the medium risk category and four sub-risks fall into the low risk category.

Based on recommendations from the industrial engineering department and project implementers (PT XYZ Lestari), risk evaluation is only in the high risk category. High criteria entry risk categories are bad weather, safety regulations not being implemented in the field, and low discipline levels. Risk evaluation results can be seen in Table 8. Risk evaluation results show that there are six triggers for critical risks, five possible critical risk handlings, and six contingency plans that can be carried out against critical risks.

Severity		1 R	2 U	3 P	4 L	5 A
I	5			18		
Mi	4	5		10	2, 25	
Mo	3	15, 22	1, 4, 16	8, 24, 27		
Ma	2	3, 11, 23, 26	7, 9, 17	6, 13, 21	12	
C	1	20, 30	19, 28	14, 29		

Occurance

Figure 9. Risk Matrix Measurement Results

Table 8. Risk Evaluation

Risk Evaluation	Trigger	Likelihood	Contingency Plan
Bad weather	1) Inaccurate weather forecast. 2) There was no planning for rain.	Reduce, Avoid	1) Close areas or surfaces are not yet completely dry. 2) Move tools and equipment to a safe place.
Safety regulations not being implemented in the field	1) This results in additional costs. 2) There was no check by the authorities.	Avoid, Switch	1) Provide fines if workers do not use complete safety tools while working. 2) It requires every worker to have a safety certification.
Low discipline levels.	1) Project executors are not chosen through a competitive process. 2) Project progress evaluation is slow.	Avoid	1) Transparency in tender opening. 2) Budget transparency for project implementation.

5. Conclusion

Based on the analysis and discussion of the data collection and processing results, it can be concluded that the project management study is known to have the critical trajectory in the activity of A–C–F–G with a total duration of 84 days and a probability of 96.16%. The average profit calculation obtained by the project implementer reached Rp 59.893.125. Risk management measurements results on manufacturing laboratory construction projects are known to be high-category risks, namely bad weather, safety regulations not being implemented in the field, and low discipline levels.

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