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Analysis of Cost Overrun & Time Overrun Causal Factors Affecting Construction Project Cost Performance Using Dematel & ANP

Ayu Adryani[1*], Tatang Akhmad Taufik [2], Haryo Dwito Armono[3]
[1]Institut Teknologi Sepuluh Nopember, Indonesia
[2]Institut Teknologi Sepuluh Nopember, Indonesia
[3]Institut Teknologi Sepuluh Nopember, Indonesia

[*]Corresponding Author: ayuadriyani1998@gmail.com

Abstract: The estimation of project costs and completion timelines are crucial aspects that need to be accurately predicted, as they are key indicators of a project's success. Issues like cost overruns and delays in project completion have become common in the construction industry. PT XYZ, a mining construction company, encountered a cost overrun in May 2023, leading to a 21.6% increase in the budget. According to the initial project baseline, it was expected to be completed by September 2023, but faced an 8-month delay. This study aims to explore the external factors causing cost and time overruns, identify the most significant factors, and propose recommendations to reduce these issues. The research methods used are Decision Making Trial and Evaluation Laboratory (DEMATEL) and Analytical Network Process (ANP) to examine the relationship between the factors and determine the most dominant one. Data was collected through questionnaires, and a threshold was set via a Focus Group Discussion (FGD) with experienced professionals in construction who played a key role in project decisions. The DEMATEL analysis, with a threshold of 0.5000, produced a relationship diagram of the criteria, and the ANP analysis, conducted using SuperDecisions software, revealed that the most influential factor affecting cost and time overruns is the accuracy of the Scope of Work (SOW) . As a result, it is recommended that PT XYZ improve project management and ensure higher accuracy in defining the SOW for future projects.

Keywords: DEMATEL, ANP, Cost Overrun, Time Overrun

INTRODUCTION

One of the economic elements that has a significant impact on a country is the development of construction projects, the existence of construction projects has an impact on economic growth, provides additional jobs, and improves the infrastructure of a country as a whole (Limantoro et al., 2023). Having a construction project that develops sustainably and stably and has good resources is the desire of every shareholder (Enshassi & Ayyash, 2014). Resources including labor, materials, and work units or equipment if not managed properly will make the management of construction projects complicated, so that project success

requires careful planning, effective communication, and strong management skills (Limantoro et al., 2023).

Construction projects often face challenges such as design changes, permits, unexpected weather conditions, and regulatory changes (Sampaio, 2022). In addition, cost overruns and project completion time overruns are major challenges in construction projects, especially in developing countries, and this can have a negative impact on the company's image (Zhang et al., 2022). A situation known as cost overrun occurs when the project cost or final cost exceeds the budgeted amount (Anugerah, 2022). Meanwhile, project completion time overruns can be interpreted as an extension of time beyond the contract time agreed in the tender, which will ultimately result in higher costs (Shanmugapriya & Subramanian, 2013).

According to Kaming et al., (2019), identified 11 time overrun variables and 7 cost overrun variables shown in Table 1 The variables causing cost overruns and construction project schedules will always change, because project management will continue to adopt new factors, new expertise, new methods or technologies and knowledge on each different project (Shehu et al., 2014).

Cost & time overrun factors can come from internal or external influences (Limantoro et al., 2023). However, after considering all aspects in the PT XYZ management meeting, it was agreed that the factors studied in this case were external factors. This decision was based on a thorough analysis showing that the influence of the external environment was more significant than internal factors. Furthermore, focusing on external factors alone is important for the company because it allows the company to identify risks that can be controlled outside the company's internal scope. In addition, consideration of these external factors allows for the development of effective mitigation strategies to reduce the risk of cost overrun and time overrun in future PT XYZ projects.

Although the development of research and applications related to the causal factors and criteria for cost & time control has been widely known (Gunawan & Hakim, 2023), different approach methods are still needed to carry out efficient and effective management, so this is important to minimize the risks of cost & time overruns (Shehu et al., 2014). Among the Multi-Criteria Decision Making (MCDM) methods, the analysis methods that can be proposed to analyze the factors causing cost & time overrun include Decision Making Trial and Evaluation Laboratory (DEMATEL) (Li, 2022), Analytical Network Process (ANP) (Kumar & Thakkar, 2017), Decision Making Trial and Evaluation Laboratory-Analytical Network Process (DEMATEL-ANP) and Zero Goal Programming (ZOGP) (Yang et al., 2023), Analytical Hierarchy Process (AHP) (Nurlia et al., 2023) and Partial Least Squares Structural Equation Modeling (PLS-SEM) (Alhammadi et al., 2024).

The technique that will be applied in this study is a combination of the Decision-Making Trial and Evaluation Laboratory - Analytical Network Process (DEMATEL-ANP) method. The selection of the DEMATEL method is adjusted to the issue of construction projects, namely multiperson and multicriteria decision makers, in addition, this research factor is also suspected of not being independent. The selection of the ANP method because it is able to analyze priority factors and calculate the correlation between criteria and subcriteria. The advantage of the DEMATEL method is that it has the ability to reduce the level of errors that do not reflect actual conditions and is one of the quantified assessment methods (Büyüközkan & Güleryüz, 2016), thus making the determination of criteria more focused and representative of the situation. In addition, the DEMATEL causal diagram can also be used as input in ANP. The purpose of this study is to analyze the factors that cause cost overrun and time overrun at PT XYZ in construction projects.

METHOD

This research is applied to the construction of PT XYZ's smelter in the construction sector. Based on the contract, this project was implemented on September 27, 2021 with an original budget agreement value of USD 373,170,000, - and a work period of 24 months. However, in reality, the agreement value exceeded the initial estimate by 26.1% and the work period was delayed by +/- 8 months, so an additional budget of USD 48,400,000 was submitted by providing a contingency fee of USD 9,000,000.

The object of this study is the analysis of cost & time overrun factors that affect the cost performance of PT XYZ projects. Initially, this study involved individuals involved in the construction phase (Project Manager, Site Manager, Manager Department). The individuals who are key persons are Project Manager, Site Manager, Deputy Project Manager, Commercial Manager.

Factor analysis uses quantitative and descriptive research types. The methodology used for data collection involves the use of observation, interviews, and a comprehensive review of relevant literature. The data collected is then analyzed using the DEMATEL and ANP techniques. Data credibility assessment is carried out through the Triangulation method, so that from the results of the research analysis, external factors to the main factors causing cost & time overruns at PT XYZ can be identified and recommendations provided to the company to minimize overruns in subsequent projects.

RESULTS AND DISCUSSION

Dematel Analysis

The assessment of the relationship between criteria and sub-criteria conducted using the DEMATEL questionnaire is presented in Table 1.

Table 1. Description of Criteria & Sub-criteria

No	Criteria	Sub-criteria
1	Technical Condition (A)	A1. Project Budget Plan
		Communication between Engineer & Procurement team
		A3. SOW Accuracy
		A4. Level of design accuracy
		A5. Manpower Engineer Qualifications
2	*Procurement*(B)	Delay in arrival of materials
		Increase in material prices due to currency fluctuations
		Vendor bids are higher than budget
		Employee qualifications
		Inadequate technical clarification process (CBE-TBE)
3	Construction (C)	Materials that do not meet specifications
		Changes in work due to design changes
		Disagreement between construction team and consultant
		Delay in project decision making
		Poor construction quality

The criteria and sub-criteria of the table above are the basis for the paired comparison matrix questionnaire according to Table 3.2. Then the matrix questionnaire is distributed and respondents will fill it in according to the DEMATEL analysis scale, namely 0, 1, 2, 3, and 4. This scale shows that one item is relatively more influential than the others. The values given by the respondents are formed into a direct-relation matrix which is then used to calculate the average matrix (Matrix A).

Total Relation (TR) Matrix

After obtaining the normalized direct relationship matrix, the next step of the DEMATEL method is to use the matrix to calculate the total of relation matrix with the formula Matrix X(1-X)1. The results can be seen in Table 2.

Table 2. Results of T Matrix Calculation

		A					B					C					D
		A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3	C4	C5	
A	A1	0.55	0.65	0.65	0.65	0.45	0.60	0.54	0.60	0.58	0.56	0.67	0.58	0.58	0.51	0.57	8.74
	A2	0.55	0.50	0.57	0.57	0.39	0.50	0.46	0.52	0.52	0.49	0.58	0.52	0.51	0.45	0.48	7.63
	A3	0.62	0.65	0.55	0.63	0.44	0.56	0.52	0.58	0.58	0.55	0.66	0.58	0.58	0.50	0.56	8.54
	A4	0.60	0.63	0.61	0.53	0.43	0.54	0.50	0.56	0.56	0.53	0.63	0.56	0.55	0.48	0.53	8.26
	A5	0.54	0.55	0.55	0.55	0.34	0.49	0.45	0.50	0.50	0.49	0.56	0.49	0.50	0.43	0.47	7.40
B	B1	0.52	0.57	0.54	0.53	0.37	0.44	0.46	0.51	0.50	0.47	0.57	0.50	0.50	0.44	0.47	7.39
	B2	0.43	0.45	0.43	0.43	0.30	0.42	0.33	0.43	0.41	0.39	0.46	0.40	0.40	0.36	0.38	6.02
	B3	0.44	0.45	0.44	0.44	0.32	0.41	0.40	0.37	0.42	0.41	0.47	0.41	0.41	0.37	0.39	6.14
	B4	0.46	0.47	0.46	0.46	0.33	0.41	0.38	0.42	0.37	0.41	0.48	0.41	0.41	0.38	0.40	6.25
	B5	0.47	0.49	0.48	0.48	0.33	0.44	0.39	0.45	0.44	0.37	0.50	0.43	0.43	0.39	0.43	6.53
C	C1	0.53	0.57	0.53	0.55	0.38	0.52	0.46	0.52	0.51	0.49	0.50	0.49	0.49	0.44	0.48	7.49
	C2	0.54	0.56	0.53	0.55	0.39	0.50	0.46	0.50	0.51	0.48	0.55	0.43	0.49	0.44	0.48	7.41
	C3	0.51	0.54	0.52	0.53	0.38	0.51	0.45	0.50	0.50	0.47	0.55	0.48	0.43	0.44	0.47	7.30
	C4	0.29	0.30	0.30	0.30	0.22	0.27	0.26	0.29	0.28	0.27	0.32	0.27	0.28	0.22	0.27	4.14
	C5	0.53	0.55	0.53	0.54	0.40	0.52	0.47	0.52	0.52	0.48	0.59	0.49	0.50	0.44	0.42	7.50
	R	7.58	7.93	7.70	7.75	5.47	7.12	6.53	7.28	7.21	6.87	8.09	7.04	7.06	6.28	6.79	7.11

After obtaining the total relationship matrix, the next step is to calculate the D and R vectors. The D vector is obtained by summing each row in the entire matrix, while the R vector is the result of summing each column. The calculation of the D and R vectors is used to obtain prominence (D+R) and relation (DR). The results of the calculation of the D and R vectors can be seen in Table 3.

Table 3. Results of DEMATEL analysis

Criteria		D	R	D+R		DR	
				Mark	Rank	Mark	Rank
Project budget plan	A1	8.74	7.58	16.32	1.00	1.15	2.00
Eng. Communication network - Procurement	A2	7.63	7.93	15.56	5.00	-0.31	9.00
Accuracy of SOW	A3	8.54	7.70	16.23	2.00	0.84	3.00
Level of design accuracy	A4	8.26	7.75	16.01	3.00	0.50	5.00
Eng. Qualification	A5	7.40	5.47	12.87	13.00	1.93	1.00
Delay in arrival of materials & tools	B1	7.39	7.12	14.51	6.00	0.27	7.00
Incremented equipment prices due to currency fluctuation	B2	6.02	6.53	12.56	14.00	-0.51	11.00
Vendor's offer price is higher than estimated	B3	6.14	7.28	13.43	11.00	-1.14	14.00
Employee qualification	B4	6.25	7.21	13.45	10.00	-0.96	13.00
Insufficient technical clarification process	B5	6.53	6.87	13.40	12.00	-0.35	10.00
Material doesn't meet specification	C1	7.49	8.09	15.58	4.00	-0.61	12.00

Work stopped as a design change	**C2**	7.41	7.04	14.45	7.00	0.38	6.00
Disagreement construction & consultant	**C3**	7.30	7.06	14.36	8.00	0.23	8.00
Delay in collection project manager's decision	**C4**	4.14	6.28	10.42	15.00	-2.15	15.00
Poor construction quality	**C5**	7.50	6.79	14.29	9.00	0.70	4.00

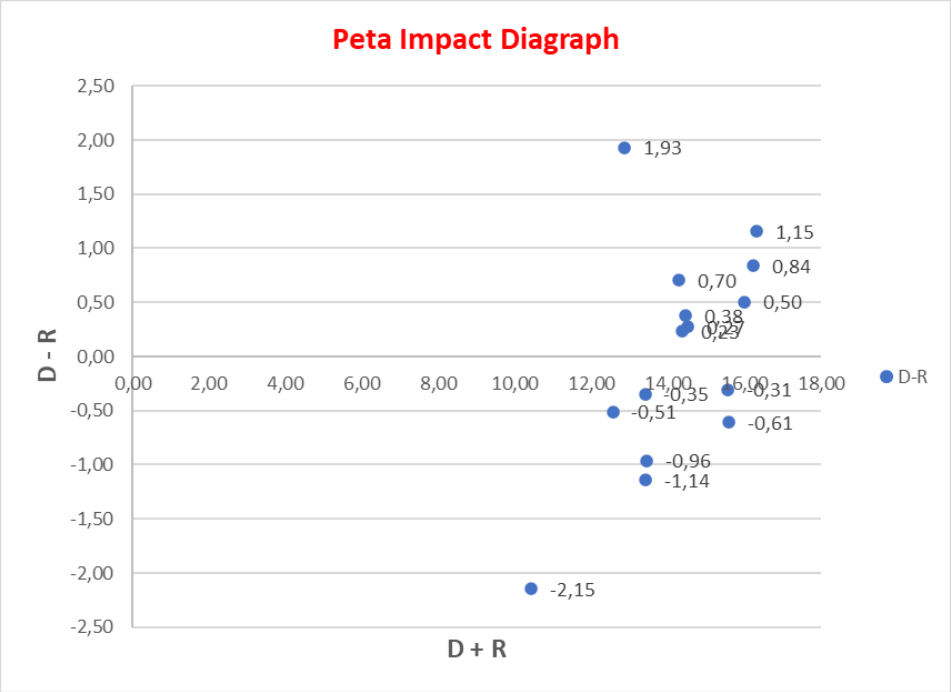

Figure 1. Impact-diagraph map

The results of the impact-diagraph map are used to determine the threshold value through the FGD method with respondents who have been involved in filling out the questionnaire. This aims to evaluate and determine the priority of the criteria. The results of the FGD show that several criteria have a significant impact that require more attention in decision making. The agreed threshold value is $\alpha = 0.50$, then this value is used to filter relevant and significant criteria, so that the results of the cost & time overrun factor analysis are more focused and accurate according to the conditions in the PT XYZ project.

Each value in the total relationship matrix will be compared with the threshold value. If the total relationship matrix value is greater than the threshold value, then the criteria have an influence or relationship with other criteria.

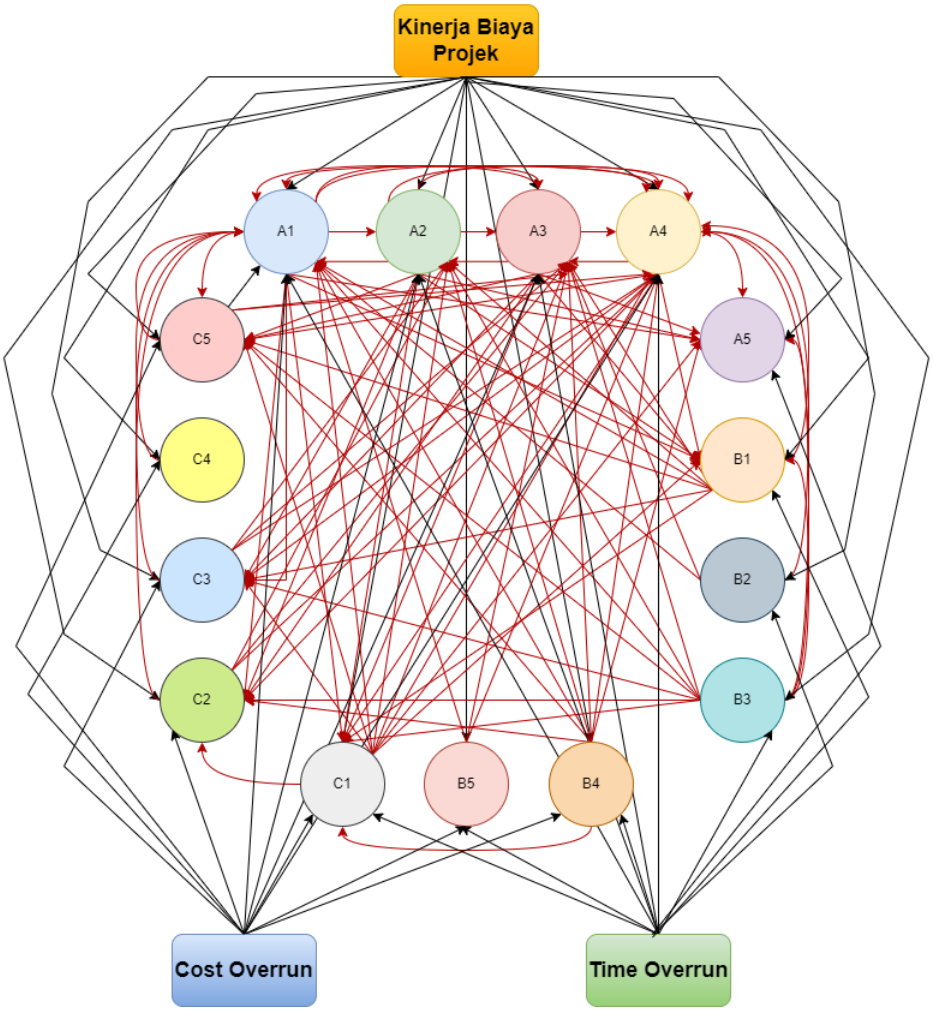

Figure 2. Network diagram of relationships between criteria

The DEMATEL network is formed from the α-cut total influence matrix. If the value is zero, then the criterion does not affect other criteria, then the composed network mapping is carried out.

Data Analysis and Interpretation

Based on the results of the analysis of DEMATEL and ANP calculations, a FGD was conducted again with 8 respondents. This is to present the results of the analysis along with discussions on managerial implications for critical aspects that need to be considered by PT XYZ project management in minimizing the risk of cost & time overrun in subsequent projects.

The results of the ANP analysis were agreed by respondents as the factors causing cost overrun and time overrun which are the key to project success. Where the accuracy of SOW in the PT XYZ project is indeed very low, this is due to the courage of stakeholders in taking risks, which is driven by the results of the high Return of Investment (ROI) analysis and the fast Payback Period. In addition, support in the form of tax holidays and tax allowances for 9 years from the government has further strengthened stakeholder confidence to continue completing this project more aggressively. So that from the results of the FGD, an overrun matrix was obtained in several scopes of construction work, as in Table 4.

Table 4. FGD Results Of The Main Factors Causing Cost & Time Overrun

Work	Information
Pilling Works	- Piling amount is higher than DFS estimate (54,278 linear meters).- No geotechnical soil investigation during DFS or budget estimate.- Large piling amount, designed by consultant.
Concrete Works	- Concrete volume increased by 11,126 cubic meters causing a cost increase of $5.48 million. - Road and drainage optimization with a volume of 16,086 cubic meters increased the cost by $4.15 million.
Steel Structure	- Increase in the amount of steel for installation by 4.13 million and the variation of fireproofing steel by 1.36 million. - Steel procurement is according to budget, but the tonnage of steel is higher than DFS and budget. - Steel installation standards in DFS do not include adequate scaffolding and safety requirements. - Fireproofing variations are required to meet GB standards (Chinese Standards).
Pipe & Valve	- Drawing changes affect pipe routing. Additional pipes and fittings are required. - Mismatch between pipe and isometric drawings. Additional pipes & fittings are required for procurement.
Mechanical	- Original design was 1Mtpa, compared to actual 1.2Mtpa. - During DFS, consultant only allowed procurement of 'Tier 2 and Tier 3' mechanical to reduce CAPEX. This may lead to endless operational maintenance & durability issues. Finally, 'Tier 1 & Tier 2' mechanical were procured by the project team. - Increase in raw materials compared to budget time.
Electrical & Instrument	- Transformer, HVAC, and earthing deficiencies from DFS increased the required budget ($3.38 million). - Installation costs increased due to many items not covered in DFS & original Estimate. - The original DFS estimate considered overhead power lines, but this was not feasible in the field (no land, too dense, too many tenants). Ultimately, the project team installed the cables in cable trays along the pipe from the substation. - CEMS Analyzer required for safety and environmental compliance. - Construction power was not considered in DFS or original budget.
International Freight	- Semi-modular shipments from China are used to minimize on-site welding, construction time and WAH. - Industrial areas have strict packaging requirements for all shipments, with structures shipped in cradles and cages, increasing shipment volumes by 10%.
Local Freight	- In DFS and original estimate, the project should be EPC by subcontractor from China, so there is only a small allocation for local delivery. - The original budget is 6 LCT trips, but a total of 45 LCT trips were used.
Packing	- Industrial areas have strict packaging requirements for all shipments, with structures shipped in cradles and cages. This adds to the cost of packaging and on-site scrap disposal is never considered during DFS.
Laydown Rental	- Storage space was never sufficient or accounted for in the DFS. - Previously, the Jakarta Hub was charged 100% to the owner but over the past year it has been charged to PT XYZ construction.
Relocation of Materials	- The Company progressively rents storage space from the industrial area, but over time the industrial area asks the Company to relocate to another location in the industrial area. - This material relocation has occurred 5 times in the past year. Additional costs are not allowed including port fees from the area manager, payment of industrial area storage space rental, customs duties, transportation from the port to the location.
Salary on cost	- 3 months delay due to Covid.- Staffing increased 3 fold from Owner Representative Team.- Project staff reduction planned to start March 2023

Work	Information
	delayed due to delays in project switchgear, final drawings for Gas Flue Chloride, upcoming changes to handle Arsenic at Pyrite Plant, delay in project downsizing to September 2023.
Site Operating Cost	- 3 months delay due to Covid.- Total headcount (Staff & Non-Staff) ~1,800 people currently.- As previously, immediate project staff reductions planned to commence March 2023 are delayed due to delays in project switchgear, final drawings for Gas Flue Chloride, upcoming changes to handle Arsenic at Pyrite Plant, delay in project downsizing to September 2023.
Consultant cost	- Additional consultant fees come from Procurement and Site Service Fees not included in the Initial Estimate as well as various engineering changes. - Paying Chinese subcontractor termination fees and charges. - Hiring Axis for contract, procurement, quality assurance and forwarding services not included in the Initial Estimate.
Site establishment	- Original AIM estimate was for a 245 person Camp (Operations + MMS Site Owner Team for construction). - After re-evaluation, with poor subcontractor performance, it was decided that PT XYZ would carry out all construction independently. Thus, the camp capacity was increased to 2,000 people (no allocation for this increase). - Laydown + Relocation of China Camp Company + camp E&I contractor, previously not allowed to be carried out independently but eventually carried out by PT XYZ
Unknown Risk	- The rainy season is historically the period of June – July.- Electrical materials, pipes, and valves are estimated.- Container Costs, related to Shipping and Transportation.- Commissioning checks.

Following up on the results of the DEMATEL-ANP analysis, managerial implications are needed to overcome these problems, so that PT XYZ will be better in the future. Table 5 explains the results of the FGD for managerial implications.

Table 5. Managerial Implications

No.	Key Findings	Required Management Response	Person responsible
1	Low SOW (Statement of Work) Accuracy	Given that the PT XYZ project is the largest integrated project in Indonesia and one of five in the world, stakeholders need to balance the courage to take risks with an emphasis on improving the accuracy of the SOW. Management must conduct a more in-depth review of the SOW to ensure that all technical and business aspects are fully covered to reduce the risk of change and uncertainty in the execution phase.	*Stakeholders & Project Managers*
2	Low Design Accuracy Level	Due to the immature SOW, design changes occur continuously. Management needs to temporarily postpone some design activities until the SOW is more complete and clear. Also, better coordination between the planning and implementation teams is needed to minimize unnecessary design changes and speed up the response time to design revisions.	Consultant & Engineer

Table 5. Managerial Implications

No.	Key Findings	Required Management Response	Person responsible
3	Project Budget Planning	Manage the budget flexibly by including contingencies for possible design changes. Budget evaluation should be done dynamically, accounting for worst-case scenarios based on design changes and SOW uncertainties.	*Commercial Manager & Project Manager*
4	Material Risk and Procurement	Adapting procurement strategies with the flexibility needed to deal with frequent design changes. Strengthening relationships with vendors to ensure material availability as per possible design changes.	*Supply chain management*& Logistics
5	Construction Quality and Team Communication	Conduct regular coordination meetings to ensure the construction team is always informed of the latest design changes. Increase training for the field team in dealing with dynamic changes that can affect construction quality.	*HR Manager & Construction Manager*
6	External Uncertainty (Prices & Changes)	Develop proactive risk mitigation strategies to deal with material price uncertainty and design changes. Prepare more flexible contracts with vendors and suppliers to accommodate last-minute changes.	*Commercial manager & Supply Chain Manager & Contract Manager*

CONCLUSION

Factors that cause cost overrun and time overrun in PT XYZ project and are related to other factors based on the DEMATEL method are project budget plan, eng. communication network - procurement, accuracy of sow, level of design accuracy, delay in arrival of material & tools, material doesn't meet specification, work stopped as a design change, disagreement construction & consultant, poor construction quality. The most dominant factor influencing cost overrun and time overrun based on the DEMATEL & ANP integration method is accuracy of SOW (0.0991) followed by level of design accuracy (0.0951) and project budget plan (0.0737). Minimizing the occurrence of cost overrun and time overrun in PT XYZ project further based on the results of DEMATEL - ANP analysis and FGD managerial implications is that project management needs to improve SOW accuracy, prepare mature design planning, manage budget with flexibility or provide contingency costs, and develop proactive risk mitigation strategies.

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