

Risk Management in the Turyapada Tower Project

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Abstract:

The construction sector in Bali Province is experiencing rapid growth, marked by strategic infrastructure projects such as the Turyapada Tower Development Project in Buleleng Regency. This project is designed as a center for digital television broadcasting, telecommunications, and as a tourism and educational destination based on local wisdom. With a height of 115 meters and located in a hilly area at 1,521 meters above sea level, the project faces high levels of complexity and risk that require systematic risk management. This study aims to identify dominant risks, analyze their ownership and mitigation strategies, and evaluate their impact on project cost and schedule using qualitative and quantitative approaches. Through brainstorming sessions with five contractor staff, questionnaire surveys distributed to project stakeholders, and Monte Carlo simulations using Crystal Ball software, 47 dominant risks were identified from an initial pool of 55 potential risks. The identified risks were predominantly related to labor shortages (inadequate number of workers), delays in material delivery, changes in the scope of work, and issues with the supply of materials and equipment. Key findings reveal that 22% of risks fall into the "unacceptable" category and 72% into the "undesirable" category, with project-related risks being the most dominant. The Monte Carlo simulation results indicate a potential project delay of 22 weeks (152 days) from the planned 450-day schedule, with only a 1.61% probability of completing on time, and a cost increase of 5.69% (approximately IDR 15.98 billion) from the original budget of IDR 280.71 billion. These findings underscore the critical importance of implementing proactive mitigation strategies to control the impact of these risks and ensure project success.

Keywords: Turyapada Tower, Risk Management, Monte Carlo

INTRODUCTION

The construction sector in Bali Province has experienced significant growth, in line with the increasing need for infrastructure development across various regions, including North Bali (Adnyana et al., 2015; Liew et al., 2021; Raeskyesa et al., 2019; Sukmaadi & Marhaeni, 2021). One of the strategic projects currently under development is the Turyapada Tower, a multifunctional tower being constructed in Pegayaman Village, Buleleng Regency. This project aims to expand the reach of digital TV broadcasts while also serving as a new tourism icon and a center for economic growth in North Bali (Tataruadmin, 2022).

Standing 115 meters tall and located at an elevation of 1,521 meters above sea level, the project faces complex technical and environmental challenges (Ahmad, 2024; Oliver-Smith, 2009). The main risks include logistical obstacles due to hilly terrain with hard rock soil conditions, weather uncertainties characterized by extreme fog and strong winds reaching 60 km/h, and potential delays in materials and equipment delivery due to limited local supplier availability. These factors could significantly affect the project's scheduled completion within 450 calendar days and may lead to substantial delays and cost overruns (Saputro, 2017).

The construction industry globally faces persistent challenges in project delivery, with studies showing that 70% of construction projects experience delays and cost overruns due to inadequate risk management (Salain et al., 2019). In Indonesia, research by Ismael (2013) indicates that construction delays are often caused by poor risk identification and mitigation strategies. The urgency of improving risk management practices in the construction industry, particularly for complex projects involving unique geographical and technical challenges, cannot be overstated. Effective risk management is essential not only for project success but also for maintaining stakeholder confidence and ensuring optimal resource allocation (Asiyanto, 2009).

Despite numerous studies on construction risk management, there remains a significant research gap in systematically analyzing risks specific to high-altitude tower construction projects in challenging terrain conditions. Previous studies such as Jaya et al. (2019) focused on hotel construction risks in urban areas, while Dewi et al. (2022) examined road improvement projects, but none have comprehensively

addressed the unique risk profile of telecommunication tower construction in mountainous regions. Furthermore, limited research has applied Monte Carlo simulation to quantify the probabilistic impact of identified risks on both schedule and cost in the Indonesian construction context. This study fills this gap by providing a systematic risk assessment framework specifically tailored to tower construction projects in challenging environmental conditions.

Risk management is necessary to systematically identify, analyze, and respond to these risks (Yetrina, 2018). The application of rigorous risk management frameworks is key to anticipating potential project failures, maintaining effective implementation, and ensuring that projects deliver value within budget and schedule constraints (Flanagan & Norman, 1993). This study addresses the critical need for evidence-based risk management practices in complex infrastructure projects by employing both qualitative and quantitative methodologies.

The objectives of this research are threefold: (1) to systematically identify and categorize all potential risks in the Turyapada Tower Development Project through comprehensive stakeholder engagement, (2) to determine the most dominant risks and their ownership allocation among project parties (owner, contractor, consultant) based on established risk allocation principles, and (3) to quantitatively analyze the probabilistic impact of identified risks on project schedule and cost using Monte Carlo simulation techniques. The theoretical benefit of this study is to contribute to the body of knowledge on construction risk management by providing empirical evidence from a unique case study of high-altitude tower construction, thereby enriching the understanding of risk behavior in challenging construction environments. The practical benefits include: (1) providing project managers and contractors with a validated risk identification and mitigation framework applicable to similar projects, (2) offering evidence-based decision support for resource allocation and contingency planning, and (3) demonstrating the utility of Monte Carlo simulation as a practical tool for risk quantification in construction projects. The implications of this research extend to policy development for construction project governance and the establishment of industry best practices for managing complex infrastructure projects in Indonesia.

MATERIALS AND METHODS

This research was conducted on the Turyapada Tower construction project located in Pegayaman Village, Buleleng Regency, Bali Province, during the project implementation phase from March to September 2023. The objective of the study is to identify and analyze dominant risks in the project and to evaluate their impact on cost and time using both qualitative and quantitative methods.

This study employs a mixed-methods research design combining qualitative risk identification and assessment with quantitative risk analysis. The qualitative phase involves risk identification and prioritization, while the quantitative phase utilizes Monte Carlo simulation to assess probabilistic impacts on project outcomes.

The data sources include primary data obtained through direct observation, interviews (brainstorming) with project experts such as the project manager, site manager, quality control manager, safety officer, and chief engineer—totaling five key personnel selected based on their direct involvement in project execution and their minimum 5 years of experience in construction management, as well as questionnaires distributed to 15 respondents selected using purposive sampling based on the following criteria: (1) direct involvement in the Turyapada Tower project, (2) minimum 3 years of experience in construction projects, and (3) expertise in at least one of the following areas: project management, engineering, procurement, or quality control. The respondent composition includes 3 project managers, 4 site engineers, 3 procurement specialists, 2 quality control officers, and 3 subcontractor representatives. Secondary data were gathered through literature studies of relevant academic journals, industry reports, and regulatory documents, and project documents such as the Bill of Materials (BOM) totaling IDR 280,713,388,612.01 and the project time schedule spanning 450 calendar days.

Data collection techniques include: (1) Direct field observation conducted over 3 site visits to document actual site conditions, work processes, and environmental constraints; (2) Brainstorming sessions held in two rounds with the five expert panels to identify potential risks based on their collective experience; (3) Structured questionnaire surveys using a 5-point Likert scale to assess risk likelihood (1=very rare, 5=very often) and consequence (1=very small impact, 5=very large impact); and (4) Follow-up in-depth interviews with experts to validate risk mitigation strategies and obtain minimum, most likely, and maximum estimates for risk impacts on cost and schedule.

Risk identification was based on the Work Breakdown Structure (WBS) which divides the project into 8 major work packages: foundation work, structural work, architectural work, mechanical-

electrical-plumbing (MEP) systems, tower crane installation, transmitter installation, elevator installation, and finishing work, and previous literature including Flanagan & Norman (1993), Godfrey (1996), and recent studies on construction risks in Indonesia by Jaya et al. (2019) and Salain et al. (2019). The identified risks were then classified into 9 categories: Planning Risk, Economic Risk, Financial Risk, Natural Risk, Project Risk, Technical Risk, Human Risk, Criminal Risk, and Safety Risk and assessed based on the frequency of occurrence (likelihood) and the level of impact (consequence) using mode analysis from the questionnaire data.

Risk assessment was carried out by multiplying the mode values of likelihood and consequence to determine the risk acceptance level using the risk matrix framework proposed by Godfrey (1996), which classifies risks into four categories: Unacceptable (score 16-25), Undesirable (score 8-15), Acceptable (score 4-6), and Negligible (score 1-3). Risks categorized as very high and high risk ("Unacceptable" and "Undesirable") were further mitigated through follow-up interviews with experts to formulate control strategies.

Risk ownership assessment refers to the risk allocation principles of Flanagan & Norman (1993), which consider the party most authorized and capable of managing the given risk based on four criteria: (1) which party can best control the risk, (2) which party can best manage the risk if it occurs, (3) which party should bear the risk if neither party can control it, and (4) whether risk transfer through insurance is appropriate.

For quantitative analysis, the dominant risks were further evaluated for their impact on project cost and time through follow-up interviews conducted individually with each of the five expert panel members to obtain their independent professional judgment on risk impact ranges and Monte Carlo simulations using Crystal Ball software. The simulations were conducted using a triangular distribution based on minimum, maximum, and most likely values of cost overruns and time delays provided by the experts. The triangular distribution was chosen because it requires only three estimates (minimum, most likely, maximum) which aligns with typical expert judgment patterns and is widely used in construction risk analysis (Sitompul et al., 2018). The Monte Carlo simulation was run for 10,000 iterations to ensure statistical stability and convergence of results. Key assumptions include: (1) risks are treated as independent events, (2) the triangular distribution adequately represents uncertainty in expert estimates, and (3) risk impacts are additive for schedule analysis. Variables simulated include: individual risk impact on schedule (in days) and individual risk impact on cost (in Indonesian Rupiah). The simulation outputs provide probability distributions for total project duration and total project cost, enabling probabilistic forecasting of project outcomes.

RESULTS AND DISCUSSION

A. Identify Risks

Based on the results of a literature study and brainstorming with five contractor staff directly involved in the implementation of the Turyapada Tower construction project, 55 risks that have the potential to affect the success of the project have been successfully identified. These risks are classified into 8 main risk sources, namely: Planning Risk (3 risks), Economic Risk (1 risk), Financial Risk (4 risks), Natural Risk (10 risks), Project Risk (14 risks), Technical Risk (6 risks), Human Risk (8 risks), Criminal Risk (1 risk) and Safety Risk (3 risks).

B. Risk Assessment

Respondents' Answers to Frequency (*Likelihood*)

The frequency distribution of respondents' mode values to likelihood of risk is presented in table 1.

Table 1. Risk Likelihood Frequency Distribution

Skala <i>Likelihood</i>	Information	Amount of Risk	Percentage (%)
1	Very Rare	0	0,00%
2	Infrequently	18	36,00%
3	Sometimes	10	20,00%
4	Often	22	44,00%
5	Very Often	0	0,00%
Total		50	100%

The most risk is on a scale of 4 (**Often**), which is as much as 44.00% of the total risk.

Respondents' Answers to the Consequences

The frequency distribution of respondents' mode values on the impact of risk is presented in Table 2.

Table 2. Frequency Distribution Consequences Risk

Scale	Consequences	Information	Amount of Risk	Percentage (%)
1		Very Small	0	0,00%
2		Small	7	14,00%
3		Medium	26	52,00%
4		Large	16	32,00%
5		Very Large	1	2,00%
Total			50	100%

The majority of risks have an influence on a scale of 3 (Medium) which is 52.00%.

C. Acceptability of Risk

The classification of the level of risk acceptance based on the results of the assessment (multiplication between *likelihood* and *consequences*) can be seen in Table 3.

Table 3. Project Risk Acceptance Rate

Risk Acceptance Category	Amount of Risk	Percentage (%)
<i>Unacceptable</i>	11	22,00%
<i>Undesirable</i>	36	72,00%
<i>Acceptable</i>	3	6,00%
<i>Negligible</i>	0	0,00%
Total	50	100%

The results show that 94% of risks fall into the category of unanticipated and unacceptable, so special attention is needed in project risk management and mitigation.

D. Risk Mitigation and Ownership

Risk Mitigation and Ownership of Unacceptable Risks

Table 4. Risk Mitigation and Ownership of Unacceptable Risks

Sources of Risk	Risk	Risk Mitigation	Risk Ownership
Natural	The pile drill tool used quickly deteriorates because the soil in the project area is hard rock	<u>Risk Reduction</u> Provides a spare drill tool to avoid delaying work when the main tool is damaged.	Contractor
		<u>Risk Reduction</u> Perform regular inspections of drill tools to detect damage early and prevent further damage.	
		<u>Risk Transfer</u> Locate a drill pile subcontractor and assign part of the drill pile work to the subcontractor	
Natural		<u>Risk Reduction</u> Increase the number of drill tools used	Contractor

Sources of Risk	Risk	Risk Mitigation	Risk Ownership
		<u>Risk Reduction</u> Perform multiple work shifts to maximize work time and increase daily work productivity	
	The pile drilling tools used have low productivity because the soil in the project area is hard rock	<u>Risk Transfer</u> Find a drill pile subcontractor and provide the best drill pile work to the subcontractor	
		<u>Risk Retention</u> Temporarily dismisses work if the weather is extreme enough and immediately resumes work if the weather has begun to improve	
Natural	Work interruption due to unpredictable weather (rain, strong winds, temperature and fog)	<u>Risk Reduction</u> Installing a strong canopy or tarpaulin in the manufacturing area to protect against inclement weather	Contractor
Project	Inadequate number of workers	<u>Risk Reduction</u> Conduct more careful planning by scheduling labor needs to avoid potential labor shortages	Contractor
Project	Delays in material delivery	<u>Risk Reduction</u> Calculating the material needs to be used, as well as ordering materials well in advance before the work is carried out and providing <i>spare</i> time to overcome the possibility of unexpected delays	Contractor
Project	Addition of scope of work beyond what is offered at RAB	<u>Risk Retention</u> Requesting <i>Site Intruction</i> (SI) from Construction Management or the owner and submitting a time <i>addendum</i> as a result of the addition of the scope of work	Construction and Construction Management
Project	Difficulties in determining the type of carving typical of North Bali to be used	<u>Risk Reduction</u> Submit several carving samples to the owner to immediately get the carving motif received	Construction Management and Planning Consultant
Technical	There is a rework work as a result of <i>design</i> changes or as a result of work errors	<u>Risk Retention</u> Makes a report to the owner that the contractor has completed the work and asks the owner for <i>Site Intruction</i> (SI) for demolition work and <i>design changes</i> according to the new design, then submits a time addendum as a result of the design change	Contractor and Contractor Management

Sources of Risk	Risk	Risk Mitigation	Risk Ownership
		<p style="text-align: center;"><u>Risk Reduction</u></p> <p>To reduce work errors, we must provide clear work instructions to workers, then conduct regular supervision and checks</p>	
Human	There is a delay in the material order process	<p style="text-align: center;"><u>Risk Reduction</u></p> <p>Carry out the material order process earlier than planned</p>	Contractor
Human	Work that has been completed is damaged due to exposure to equipment from other work	<p style="text-align: center;"><u>Risk Reduction</u></p> <p>Provides protection for finished work and ensures all workers are careful in sensitive work areas</p>	Contractor
Criminal	Destruction or loss of material	<p style="text-align: center;"><u>Risk Reduction</u></p> <p>Make sure all materials are stored in a safe place and install additional security systems such as surveillance cameras or security guards to monitor the material storage area</p>	Contractor

Risk Mitigation and Ownership of *Undesirable Risks*

Table 5. Risk Mitigation and Ownership of *Undesirable Risks*

Sources of Risk	Risk	Risk Mitigation	Risk Ownership
Planning	There is a continuous change in design	<p style="text-align: center;"><u>Risk Reduction</u></p> <p>Ensure that the design is approved by <i>the owner</i> so that the design is in accordance with the desired function so that there is no design change more than once</p>	Construction Management
Economics	There is an increase in material prices	<p style="text-align: center;"><u>Risk Reduction</u></p> <p>Makes <i>an initial contract</i> commitment to <i>the supplier</i> and includes in the contract clause that there is no increase in material prices</p>	Contractor
Finance	There is a labor strike due to late payment of wages	<p style="text-align: center;"><u>Risk Reduction</u></p> <p>Carry out labor payment procedures on time so that there are no delays in wage payments</p>	Contractor

Sources of Risk	Risk	Risk Mitigation	Risk Ownership
		<p><u>Risk Reduction</u></p> <p>Prepare sufficient reserve funds and provide cash to the workforce to anticipate possible late payments</p>	
Natural	The dew that is so thick in the project area causes the diesel used in the heavy equipment to mix with water so that the heavy equipment is damaged	<p><u>Risk Reduction</u></p> <p>Perform regular inspections on heavy equipment to detect these problems so that they can prevent damage to the equipment</p>	Contractor
		<p><u>Risk Reduction</u></p> <p>Increase the number of heavy equipment used for the excavation process</p>	
Natural	The productivity of heavy equipment in excavation work is low due to the condition of the soil being hard rock	<p><u>Risk Reduction</u></p> <p>Perform multiple work shifts to maximize work time and increase daily work productivity</p>	Contractor
		<p><u>Risk Transfer</u></p> <p>Finding sub-contractors to work on the excavation process wholesale</p>	
Natural	Labor turnover has great value due to extreme weather in the project area	<p><u>Risk Retention</u></p> <p>Immediately add to the workforce if there is a workforce that leaves</p>	Contractor
Natural	Waste concrete material in borpile work is large due to the condition of the soil which is hard rock	<p><u>Risk Reduction</u></p> <p>Conduct a thorough geotechnical study before starting the project tender to understand the soil condition in the project area after which the concrete waste material is appropriately included in the analysis according to the soil condition in the field</p>	Contractor
Project	Delays in the heavy equipment mobilization process	<p><u>Risk Reduction</u></p> <p>Carry out the process of mobilizing heavy equipment early before the implementation of work in the field</p>	Contractor

Sources of Risk	Risk	Risk Mitigation	Risk Ownership
Project	Changes in the implementation schedule	<p><u>Risk Retention</u></p> <p>Rearrange execution schedules by prioritizing critical work and allocating additional time for work that could potentially be delayed</p>	Contractor and Construction Management
Project	Difficulty finding <i>concrete</i> suppliers	<p><u>Risk Retention</u></p> <p>Finding a local concrete supplier in the project site area</p>	Contractor
Technical	Error in the implementation method in the process of excavating the tower foundation	<p><u>Risk Reduction</u></p> <p>Making an effective working method for tower foundation excavation work, where the existing soil condition is hard rock, the excavation of the borpile foundation with a large diameter is carried out gradually by using the smallest diameter tool first and then gradually replaced with a larger diameter</p>	Contractor
Technical	Lack of material orders due to <i>large material</i> waste	<p><u>Risk Reduction</u></p> <p>Accurately calculates material requirements before the order process is carried out by considering waste material based on technical calculations and previous project experience</p>	Contractor
Natural	The difficulty in carrying out the excavation process is due to the dominant soil condition of hard rocks	<p><u>Risk Reduction</u></p> <p>Making a more effective working method by using a heavy equipment <i>breaker</i> first and then the excavation process</p>	Contractor

Sources of Risk	Risk	Risk Mitigation	Risk Ownership
Natural	Strong winds reach 60 km/h resulting in <i>low</i> tower crane productivity	<p><u>Risk Reduction</u></p> <p>Install anemometers at the project site to monitor wind speed directly, then do work that requires a crane when the wind is not too strong, for example in the morning or at night, if the wind conditions are strong, then plan alternative work that does not use a <i>tower crane</i></p>	Contractor
Project	There is a change in the specifications of the material used	<p><u>Risk Reduction</u></p> <p>Ensuring the project contract includes clauses governing the procedure for changing material specifications, including the approval process and the responsibility of additional costs.</p>	Contractor
Project	Difficulties in finding expert labor for stone carving jobs	<p><u>Risk Reduction</u></p> <p>Conduct surveys and find information related to the workforce of stone carving experts</p>	Contractor
Human	Error in reading the drawings from the contractor	<p><u>Risk Reduction</u></p> <p>Carry out regular daily coordination between <i>supervisors and site managers</i> to ensure that the work program to be carried out is appropriate</p>	Contractor
Natural	Heterogeneous soil conditions require many soil test samples	<p><u>Risk Reduction</u></p> <p>Conduct soil tests early before the project is implemented so as not to interfere with the project implementation process, then the cost of the soil test implementation is included in the bid to anticipate cost overruns</p>	Contractor and Construction Management
Project	Difficulties in finding terrestrial transmitter suppliers	<p><u>Risk Reduction</u></p> <p>Finding a transmitter supplier abroad according to specifications and then conducting an order process early to anticipate late material delivery</p>	Contractor

Sources of Risk	Risk	Risk Mitigation	Risk Ownership
		<p><u>Risk Transfer</u></p> <p>Contracting with a terrestrial transmitter subcontractor and ensuring that materials can be installed according to <i>the planned</i> schedule</p>	
Project	Difficulties in finding an elevator supplier	<p><u>Risk Reduction</u></p> <p>Finding a supplier lift abroad according to specifications and then placing an order early to anticipate late material delivery</p>	Contractor
		<p><u>Risk Transfer</u></p> <p>Contracting with elevator subcontractors and ensuring that materials can be installed according to <i>the planned</i> schedule</p>	
Human	Inadequate quality of labor	<p><u>Risk Reduction</u></p> <p>Ensuring that the contractor uses the services of a foreman who is experienced in his field</p>	Contractor
Safety	Occurrence of work accidents in the project area	<p><u>Risk Reduction</u></p> <p>Identify potential hazards and risks in the workplace, such as accidents due to heavy equipment, falls from heights, or exposure to hazardous chemicals. Then make sure all workers use safety equipment that is appropriate for their job, such as helmets, safety shoes, safety harnesses, and protective goggles.</p>	Contractor
Planning	Delays in reaching a design agreement with the owner	<p><u>Risk Transfer</u> <u>Invite</u></p> <p><i>the owner</i> to be actively involved in the design process, including strategic decisions and design approvals, then ensure that the <i>owner</i> is involved in the <i>design</i> meeting and has the opportunity to provide feedback on a regular basis</p>	Construction Management and Planning Consultant

Sources of Risk	Risk	Risk Mitigation	Risk Ownership
Planning	Potential risk of design errors, so that implementation time is late and there is a rework of work	<p><u>Risk Reduction</u></p> <p>Conduct preliminary verification of the design to ensure that all technical and functional aspects have been adequately considered before commencing construction.</p>	Planning Consultant
Finance	There is a delay in payment by the contractor to the supplier of building materials	<p><u>Risk Reduction</u></p> <p>a gradual or progressive payment system, where payments are made according to material receipts, It can help avoid the accumulation of large payment delays</p>	Contractor
Finance	Late payment by the main contractor to the subcontractor	<p><u>Risk Reduction</u></p> <p>a gradual or progressive payment system, where payments are made according to the progress of the project, It can help avoid the accumulation of large payment delays</p>	Contractor
Finance	Late payment by the owner	<p><u>Risk Reduction</u></p> <p>In the contract, include a clause that governs the dispute resolution mechanism related to late payments, as well as fines or other consequences if payments are not made according to the agreed schedule.</p>	Owner
Project	Difficulty in accessing the mobilization and demobilization of the heavy equipment to be used	<p><u>Risk Reduction</u></p> <p>Conduct initial mapping and planning of the location of the mobilization and demobilization of heavy equipment before starting the project. Make sure the location is easily accessible by the heavy equipment to be used.</p>	Contractor
Project	The quality of the work does not correspond to the quality of the planning technical specifications	<p><u>Risk Reduction</u></p> <p>Conducting regular and periodic checks by QC related to the work carried out to meet the quality as planned</p>	Contractor

Sources of Risk	Risk	Risk Mitigation	Risk Ownership
Technical	The amount of equipment is less than required	<u>Risk Reduction</u> Making calculations of the need for tools to be able to meet predetermined targets	Contractor
Technical	There are changes in structural and architectural design that have an impact on MEP's work	<u>Risk Reduction</u> Ensure that there is intensive initial coordination between the structure/architecture design team and the MEP team. This is important to ensure that all aspects of the design are thoroughly accounted for and that no conflicts occur on the ground.	Planning Consultant
Technical	Presence of leaks or damage in the plumbing system	<u>Risk Reduction</u> Make sure the plumbing system design has been planned in detail and meets applicable technical standards. This includes the selection of the right material and the installation in accordance with the technical guidelines.	Contractor
Human	Errors during coordinate surveys	<u>Risk Reduction</u> Ensure that the assigned team of surveyors has adequate experience and expertise in conducting coordinate surveys for construction projects.	Contractor
Human	Coordination between structural, architectural and MEP workers is poor	<u>Risk Reduction</u> Conduct regular coordination between structural, architectural, and MEP teams to discuss work schedules, design developments, and system integration. Make sure all parties are involved in conveying and understanding each other's needs.	Contractor
Safety	Heavy equipment slips due to steep ground contours	<u>Risk Reduction</u> Conduct in-depth mapping and evaluation of the work area before starting the project. Identify areas that have steep soil contours and determine a safe working strategy for the machine.	Contractor

Sources of Risk	Risk	Risk Mitigation	Risk Ownership
		<u>Risk Retention</u>	
Safety	Traffic accidents occur during the heavy equipment mobilization process	Coordinating with authorities such as the local police to obtain special permits or escorts during the mobilization of heavy equipment. Make sure to comply with all applicable traffic rules.	Contractor

E. Analysis of Major Risk Impact on Project Schedule

The analysis was conducted through structured brainstorming with five contractor staff who were directly involved in the implementation of the Turyapada Tower Project. Their opinions, based on their respective experiences, were mutually agreed upon and then used as the basis for the Monte Carlo simulation.

Table 4. Probability of Project Completion Duration

Schedule Type	Duration (Days)	Probability
Planned Schedule	450	1.61%
Fastest Schedule Due to Risk	574	83.91%
Longest Schedule Due to Risk	630	99.88%
Monte Carlo Schedule (Mean)	602	96.51%

Based on the results in Table 6, the Monte Carlo simulation (Mean) indicates that the expected project completion duration is 602 days, with a probability of 96.51%. Meanwhile, the original planned duration of 450 days has only a 1.61% probability of being achieved. This indicates that the planned schedule is unrealistic and poses a significant risk of delay.

F. Analysis of Major Risk Impact on Project Cost

The analysis was conducted through structured brainstorming with five contractor staff directly involved in the Turyapada Tower Project. Their mutually agreed insights based on experience were then used as the basis for the Monte Carlo simulation.

Table 5. Monte Carlo Simulation Results (Project Cost)

No	Description	Total Cost (IDR)	Cost Increase Percentage
1	Budget Plan (RAB)	280,713,388,612.01	0.00%
2	Minimum Impact on Cost Increase	293,514,491,188.12	4.56%
3	Maximum Impact on Cost Increase	299,753,374,356.22	6.78%
4	Most Likely Impact on Cost Increase	296,633,932,772.17	5.67%
5	Monte Carlo Simulation Mean	296,694,315,789.00	5.69%

Table 6. Probability of Project Cost

No	Description	Total Cost (IDR)	Probability
1	Budget Plan (RAB)	280,713,388,612.01	1.19%
2	Minimum Impact on Cost Increase	293,514,491,188.12	70.09%
3	Maximum Impact on Cost Increase	299,753,374,356.22	99.46%
4	Monte Carlo Simulation Mean	296,694,315,789.00	94.59%

The results in Table 9 show that the estimated total project cost based on the Monte Carlo simulation (mean) is IDR 296,694,315,789.00, with a 94.59% probability of occurrence. Meanwhile, the total cost according to the Budget Plan (RAB) of IDR 280,713,388,612.01 has only a 1.19% probability of being achieved. This indicates that the budget plan is unrealistic and potentially leads to cost overruns during project implementation.

CONCLUSION

Based on the results of the study, 50 risks were identified in the implementation of the Turyapada Tower Construction Project, with 47 categorized as major risks, consisting of 11 unacceptable risks and 36 undesirable risks. Project-related risks were the most dominant category in both groups. To anticipate negative impacts, 58 mitigation actions were carried out for the major risks, with the largest allocation of risk ownership assigned to the contractor as the main project executor. These risks have significant impacts on the project's schedule and budget. The Monte Carlo simulation results show that the project is at risk of a 22-week (154-day) delay from the planned schedule and a cost overrun of 5.69% from the total budget (RAB), highlighting the critical need for effective risk management to ensure project success.

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