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Risk Analysis for the Alfamart Warehouse Construction Project in Palangkaraya, Central Kalimantan

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Abstract: The operational success and completion performance of a logistics warehouse construction project heavily depend on precise schedule adherence and rigorous budget control. In field execution, however, contractors frequently encounter unpredictable environmental factors that lead to severe schedule overruns and cost inflations. These challenges become particularly acute in large-scale facilities featuring wide-span structural steel framing erected over challenging peat soil geotechnics. This empirical study aims to analyze critical risk variables and devise comprehensive mitigation frameworks for the construction of the Alfamart Distribution Warehouse in Palangka Raya, Central Kalimantan, covering a 30,000 m² site area and a 13,000 m² footprint. A quantitative descriptive-analytical framework was employed, collecting field data via structured questionnaires, site observations, and expert interviews involving 38 senior practitioners across the project owner (PT Sumber Alfaria Trijaya Tbk), main contractor (PT Primatama), and supervising consultant (PT Rekajasa). Statistical verification utilized Spearman's rank correlation for item validity and Exploratory Factor Analysis (EFA) to verify measurement unidimensionality through McDonald's omega hierarchical coefficient (ωh) alongside Cronbach's Alpha reliability indices. Risk acceptability thresholds were categorized using mode-based risk matrices against Godfrey's evaluation criteria. Out of 43 evaluated variables, 41 (95.3%) were determined as major delay-inducing factors and 37 (86.0%) were major cost-inducing factors. The highest priority unacceptable risks stem from peat soil consolidation leading to foundation settlement (peak index value of 0.750), extreme weather disruptions, global steel price volatility under lump-sum contracts, heavy equipment rental rate spikes, worker burnout, fatigue from excessive overtime, scarcity of AWS-certified structural welders, and inter-island river transport delays. Seven validated mitigation clusters were established, prioritizing geotechnical field engineering and supply chain resilience.

Keywords: *Risk Management, Construction Project, Warehouse, Steel Structure, Peat Soil, Risk Acceptability, Risk Mitigation.*

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I. INTRODUCTION

The pace of national economic growth and the rapid expansion of the modern retail sector in Indonesia require the support of a robust and efficient logistics and supply chain infrastructure with a responsive distribution network. PT Sumber Alfaria Trijaya Tbk (Alfamart), as one of the largest FMCG (Fast-Moving Consumer Goods) retail network operators in Indonesia, consistently makes strategic investments to strengthen the reliability of its regional supply chain. This crucial step has been taken to reduce delivery times, minimise stock vulnerabilities at the retail outlet level, and optimise the cost efficiency of logistics operations on a sustainable basis. One of the key infrastructure investments undertaken is the Regional Distribution Centre (Regional Distribution Centre / Warehouse) located in Palangka Raya, Central Kalimantan Province. This infrastructure project, which supports the retail network, was built on a 30,000 m² site with a total floor area of 13,000 m². It serves as the main logistics distribution hub, supplying goods to hundreds of Alfamart retail outlets across all districts and cities in Central Kalimantan.

From a civil engineering structural design perspective, the Alfamart Warehouse in Palangka Raya utilises a main structural system comprising a wide-span structural steel portal frame, which employs high-quality wide-flange (WF) and H-beam steel sections in the main columns, rafters and

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wind bracing. The choice of wide-span steel profiles was based on their significant technical advantages over conventional reinforced concrete structures, including: a very high strength-to-weight ratio; optimal flexibility in interior layout without central columns (clear-span structure), thereby maximising manoeuvring space for forklift trucks and the arrangement of high-bay racking systems; as well as the speed of component assembly on site. Nevertheless, the construction of wide-span steel frames in Central Kalimantan presents a very high level of technical and managerial complexity due to a combination of complete reliance on off-island material supplies and the extremely challenging local geotechnical and environmental conditions.

The geotechnical conditions at the construction site in Palangka Raya are characterised by layers of soft soil and peat, with thicknesses ranging from shallow to very deep. Physically and mechanically, peat soil is characterised by a very high natural moisture content (natural moisture content > 300 per cent), a high degree of water saturation, low permeability, a very low unit weight, and extremely limited shear strength. The most critical characteristic of peat soil deposits is their exceptionally high compressibility, which triggers the potential for long-term secondary settlement as well as secondary settlement caused by the live loads of the structures built upon them. These extreme geotechnical conditions present the most crucial engineering challenges in the construction of substructures, such as the driving of foundation piles, the construction of pile caps, and the construction of concrete floor slabs within the warehouse (slab-on-grade). Inaccurate ground treatment or errors in calculating the bearing capacity of the subsoil carry a high risk of causing differential settlement of the foundations, tilting of steel portal columns, cracking of floor slabs, and even failure of connections between steel structural members.

In addition to local geotechnical challenges, construction on site was hampered by the limited availability of large-scale steel sections on the local market in Central Kalimantan. The majority of the steel sections—including WF sections, H-beams, gusset plates and high-strength friction grip bolts—had to be sourced from manufacturers or major distributors on the island of Java. This inter-island logistics distribution chain relies heavily on a fleet of sea-going vessels (Ro-Ro ships and barges), followed by transport via Kalimantan's river routes (such as the Kahayan River). These water transport routes are highly vulnerable to disruptions caused by climate and weather uncertainties, such as high waves in the Java Sea during the west monsoon season, as well as the silting up of river navigation channels during the dry season, which frequently causes vessels to run aground. Delays in the delivery of steel materials to the project site directly halt the erection process and trigger a domino effect of time delays across the entire critical path sequence of works.

From a human resources management perspective, the construction of wide-span steel structures demands a high level of specialist qualifications and expertise. The process of lifting and assembling steel portals standing tens of metres tall requires operators qualified to handle heavy-tonnage cranes, as well as an experienced team of riggers. On the other hand, the execution of structural welded joints at critical points requires welders who hold official qualifications in accordance with international standards (such as those of the American Welding Society (AWS) or the Director-General of New and Renewable Energy, Energy Conservation, and Oil and Gas (EBTKE/Migas)). The limited number of certified welders at the local level in Central Kalimantan has forced contractors to bring in specialists from outside the region or to utilise local labour, with the risk of a decline in the quality of the welding work (such as defects including porosity, slag inclusions or weld cracks), which could result in rejection by the supervising consultants. Furthermore, the pressure to meet accelerated schedule targets, which has been channelled into an extreme policy of night-time overtime, risks triggering burnout and cumulative physical exhaustion amongst workers, which has a devastating impact on productivity and increases the potential for workplace accidents.

From the perspective of financial management and contract administration, the Alfamart Palangka Raya Warehouse construction project adopted a lump-sum (fixed-price) contract scheme. Under this contract scheme, the entire risk associated with fluctuations in the prices of construction materials, increases in heavy machinery hire rates, and cost overruns arising from mobilisation is borne entirely by the contractor. Uncertainties in the global economic climate, which have triggered a surge in global steel prices, currency exchange rate fluctuations and rising fuel prices, have indirectly increased the costs of heavy machinery hire and logistics operations. These conditions carry a high risk of causing cost overruns and cash flow bottlenecks for the contractor.

Documentation and an initial assessment at the project site, a number of significant constraints were identified that have the potential to disrupt project performance, including: (1) slow progress in foundation preparation due to high groundwater levels and peatland subsidence; (2) uncertainty regarding the arrival schedule of ships transporting steel materials from Java; (3) frequent revisions to working drawings (design changes) due to adjustments to actual site ground conditions; (4) a shortage of AWS-certified welders; (5) the occurrence of extreme weather events—heavy rain accompanied by strong winds—which forced the suspension of crane operations; (6) increased heavy machinery hire costs due to time extensions; and (7) the implementation of SMKK occupational safety criteria, which has not yet been optimally implemented. The complexity of these vulnerabilities underscores the urgency of implementing a systematic, measurable and integrated risk management approach.

Relevant previous research has been carried out by William Pratama Rusli (2024) on risk assessment for the Decommerce warehouse construction project in Banjarmasin, which examined technical, logistical and managerial factors. The novelty of this study lies in its specific focus on the construction of a regional-scale retail logistics warehouse featuring wide-span steel portal frames on the extreme peatlands of Palangka Raya. Furthermore, this study makes a methodological contribution by demonstrating the

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unidimensionality of the risk measurement model using exploratory factor analysis (EFA) based on the hierarchical McDonald's omega coefficient (WH) to complement the Cronbach's Alpha reliability test.

Based on the background and context of the issue outlined above, this study has been designed with the following strategic objectives: (1) to identify and empirically test the risk variables that have the most dominant influence as constraints on project schedule performance (time delay) and project costs (cost overrun); (2) to analyse risk acceptability based on a mode matrix and the Godfrey Scale, drawing on the objective perceptions of practitioners in the field; and (3) to formulate and validate a practical and relevant tactical risk mitigation strategy framework to manage the vulnerabilities of similar warehouse construction projects in the future.

II. METHODS

This study was designed using a descriptive-analytical quantitative approach combined with integrated qualitative analysis (a mixed-methods explanatory sequential design). The quantitative approach was utilised to measure the frequency of occurrence and the severity of impact of each risk variable based on the respondents' objective perceptions, as gathered through a structured questionnaire. Meanwhile, the qualitative approach was applied to investigate the root causes of technical problems (root cause analysis) through in-depth interviews, as well as to confirm the validity of the recommended mitigation strategies in consultation with competent senior experts.

The research location focused on the site of the Alfamart Palangka Raya Warehouse Construction Project in Central Kalimantan Province. The research subjects comprised all practitioners, managers and construction engineers who were directly and actively involved in the planning, implementation and supervision phases of the project. The target population comprises the three main stakeholder entities of the tripartite construction project, namely the main contractor (PT Primatama), the project owner (PT Sumber Alfaria Trijaya Tbk), and the construction management supervision consultant (PT Rekajasa).

The sampling technique employed a non-probability purposive sampling method. The criteria for sample selection were based on precision qualifications, including: (1) a formal educational background of at least a Bachelor's or Master's degree (S1/S2) in Civil Engineering, Architecture or Construction Management; (2) having at least 3 to 15 years' practical experience in the management of building or warehouse construction projects; and (3) holding a managerial or strategic technical position within the project's organisational structure. Based on these strict criteria, a total sample of 38 expert respondents was obtained, comprising 18 respondents from the Main Contractor (PT Primatama), 13 respondents from the Owner (PT SAT Tbk), and 7 respondents from the Supervising Consultant (PT Rekajasa).

The process of developing the questionnaire began with a comprehensive review of the scientific literature, an analysis of technical documents, and a synthesis of construction safety regulations. Prior to mass distribution to the target respondents, the research risk variables and indicators were first validated by two senior experts (expert judgement) who hold Senior Project Manager qualifications and have over 15 years' experience working on warehouse and wide-span steel building projects. The results of the expert validation confirmed 43 risk variable indicators, grouped into nine main review aspects, namely: Natural Aspects (4 indicators), Economic Aspects (4 indicators), Technical Aspects (7 indicators), Project Aspects (11 indicators), Environmental Aspects (2 indicators), Human Aspects (4 indicators), Safety Aspects (4 indicators), Security Aspects (3 indicators), and Financial Aspects (4 indicators).

Primary data collection was carried out by completing a structured questionnaire using a 5-point Likert scale (1 = Very Low / Very Rarely, 2 = Low / Rarely, 3 = Fair / Moderate, 4 = High / Often, 5 = Very High / Very Often). The questionnaire was designed separately to measure two dimensions of the project's objectives, namely: (a) the frequency/likelihood of a risk occurring; (b) the extent of a risk's impact on schedule delays; and (c) the extent of a risk's impact on cost overruns. Primary data collection was supplemented by field observations and secondary documents such as the Detailed Engineering Design (DED), S-curve schedules, and contract documents. The stages of quantitative data analysis and statistical testing were carried out systematically through the following procedures:

- Item Validity Test: Spearman's rank correlation test was used in SPSS version 29.0. The correlation between the scores of the indicator items and the total factor score was tested at a significance level of $\alpha = 0.05$. An indicator was deemed valid if it yielded a p-value < 0.05.
- Reliability and Unidimensionality Tests: Applying Exploratory Factor Analysis (EFA) with a bifactor model to calculate the hierarchical McDonald's omega (ωh) value in order to demonstrate the unidimensionality of the instrument (a measure of whether the questionnaire predominantly measures a single main construct without being distorted by sub-factors). The criterion for unidimensionality is met if the value of ωh is greater than 0.80. The internal consistency of the instrument is then verified using Cronbach's Alpha (threshold > 0.60).
- Risk Acceptability Analysis: The level of risk acceptability is calculated using the mode (Mo) of the perceived frequency and impact. The Risk Index is formulated as: Risk Index = Mode of Frequency × Mode of Impact. The calculated Risk Index is then categorised into the Godfrey Scale, comprising four levels: Unacceptable (Very High / Unacceptable, Index ≥ 0.563 or Matrix Value ≥ 15), Undesirable (High / Undesirable, $0.200 \leq$ Index < 0.563), Acceptable (Moderate / Acceptable, $0.100 \leq$ Index < 0.200), and Negligible (Very Low / Negligible, Index < 0.100).
- Cross-checking Root Causes and Validating Mitigation Measures: For risk variables categorised as 'Unacceptable' (critical priority), a root cause analysis

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was carried out through in-depth interviews. Based on these root causes, a draft set of mitigation strategy recommendations was drawn up, which was subsequently validated by three senior experts (a Senior Project Manager at PT Primatama, a Distribution Centre Specialist at PT SAT Tbk, and a Senior Project Manager at PT Rekajasa).

III. RESULTS

Data collection via the distribution of questionnaires to 38 expert respondents yielded a response rate of 100 per cent. The detailed profiles and characteristics of the respondents are as follows: (a) By institutional representation: 18 respondents from the main contractor PT Primatama (47.4 per cent), 13 respondents from the project manager/owner PT SAT Tbk (34.2 per cent), and 7 respondents from the supervisory consultant PT Rekajasa (18.4 per cent); (b) By formal educational qualification: 33 respondents held a Bachelor's degree in Civil Engineering (86.8 per cent), 2 respondents held a Master's degree in Civil Engineering (5.3 per cent), 2 respondents held a Bachelor's degree in Architecture (5.3 per cent), and 1 respondent held a Bachelor's degree in Administration (2.6 per cent); (c) Based on professional work experience in the construction sector: 26 respondents had 6–10 years' experience (68.4 per cent), 7 respondents had 3–5 years' experience (18.4 per cent), and 5 respondents had 11–15 years' experience (13.2 per cent). The respondents' solid educational background and practical experience ensure the credibility and reliability of the qualitative and quantitative data collected.

- *Validity Testing of the Research Instrument*

The item validity test for the questionnaire was conducted using Spearman's rank correlation in SPSS version 29.0 on 38 respondent response sheets. The test was carried out separately for the three measurement dimensions, namely likelihood, the impact of delays, and the impact of financial losses. The results of the statistical data analysis confirmed that all 43 risk variable indicators tested yielded significance values (P-values) ranging from 0.000 to 0.028, all of which were below the significance threshold of $\alpha = 0.05$ (P-value < 0.05). It can therefore be concluded that all 43 risk variable indicators are statistically valid and possess construct validity for use in the subsequent stages of data analysis.

- *Reliability and Unidimensionality Tests (McDonald's Omega & Cronbach's Alpha)*

The instrument reliability testing in this study combined exploratory factor analysis (EFA) with bifactor modelling to measure the hierarchical McDonald's omega (ωh) coefficient and Cronbach's alpha coefficient. The test of McDonald's hierarchical omega aims to demonstrate the unidimensionality of the risk measurement instrument, namely to ensure that the variance in the total questionnaire scores is truly dominated by a single general factor (general risk factor) and is not the result of an artefact arising from the grouping of aspects.

The results of the two-factor EFA calculation yielded a hierarchical McDonald's omega (ωh) value of 0.848 for the likelihood dimension, 0.830 for the time delay impact dimension, and 0.848 for the cost loss impact dimension. As all ωh values exceed the critical threshold of 0.80 (ωh > 0.80), the research instrument is proven to validly fulfil the assumption of unidimensionality. This high degree of unidimensionality provides strong theoretical justification for the use of Cronbach's alpha as a measure of internal consistency. The results of the Cronbach's alpha reliability test are presented in Table 1.

Table 1 Results of the Cronbach's Alpha Reliability Test by Measurement Dimension

Measurement Dimension	Cronbach's Alpha Value	Reliability Rating
Likelihood	0,845	Highly Reliable / Consistent
Impact of Project Delays	0,873	Highly Reliable / Consistent
Impact of Financial Losses	0,729	Reliable / Consistent

As shown in Table 1, all measurement dimensions yielded Cronbach's alpha coefficients above the minimum criterion of 0.60 (Cronbach's alpha > 0.60). The 'impact of delays' dimension recorded the highest internal consistency with a value of 0.873, followed by the 'probability' dimension at 0.845 and the 'impact of cost losses' dimension at 0.729. These results confirm that the questionnaire instrument possesses a very high level of reliability and internal consistency for measuring project risk.

- *Analysis of Risk Acceptability Levels*

Risk Acceptability Analysis is carried out by multiplying the mode value of the frequency of risk occurrence by the mode value of its impact on the project objectives. The resulting Risk Index is then categorised according to the Godfrey Scale. Based on an analysis of 43 risk indicator variables, the distribution of risk acceptance categories in the dimensions of time delays and financial losses is as outlined below.

With regard to project delays, the distribution of risk categories was as follows: (1) the 'Unacceptable' category (Very High / Critical), comprising 7 variables (16.3 per cent); (2) the 'Undesirable' category (High / Dominant), comprising 34 variables (79.1 per cent); and (3) the 'Acceptable' category (Moderate), comprising 2 variables (4.7 per cent). Taken together, the Unacceptable and Undesirable categories indicate that 41 variables (95.3 per cent) constitute dominant risks that significantly affect project schedule delays.

Meanwhile, with regard to the financial cost losses of the project, the following distribution of risk categories was obtained: (1) the 'Unacceptable' (Very High/Critical) category, comprising 5 variables (11.6 per cent); (2) the 'Undesirable' category (High / Dominant), comprising 32 variables (74.4 per cent); and (3) the 'Acceptable' category (Moderate), comprising 6 variables (14.0 per cent). Taken together, the Unacceptable and Undesirable categories confirm that 37 variables (86.0 per cent) are classified as

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dominant risks that have a significant impact on project cost overruns. In both measurement dimensions, not a single variable was categorised as Negligible (0 per cent), indicating that all identified risk variables carry a high degree of relevance in practice.

➢ *Identification of the Highest-Priority Risks (Unacceptable)*

Risks with the highest critical priority categorised as 'Unacceptable' (with a Risk Index value ≥ 0.563 or a matrix score ≥ 15) are key risk factors that could prove fatal to the achievement of project targets and therefore require urgent mitigation measures. Details of the risk variable indicators categorised as 'Unacceptable' for the dimensions of time delays and cost losses are presented in Table 2 and Table 3.

Table 2 Critical Priority Risks Relating to Project Delays (Unacceptable Category)

Code	Critical Risk Variable Identifier	Risk Index	Godfrey Scale Category
X1.3	The presence of soil/peat causes settlement	0,750	Unacceptable
X1.1	Drastic changes in weather conditions at the project site	0,563	Unacceptable
X6.1	Workers feel burnt out whilst carrying out their work	0,563	Unacceptable
X6.4	Physical exhaustion of workers due to excessive overtime	0,563	Unacceptable
X8.1	Loss of materials and tools at the project site	0,563	Unacceptable
X4.1	Shortage of skilled labour (AWS-certified welders)	0,563	Unacceptable
X3.3	Delays in steel deliveries from off-island suppliers	0,563	Unacceptable

Table 3 Critical Priority Risks Relating to Financial Losses on the Project (Unacceptable Category)

Code	Critical Risk Variable Identifier	Risk Index	Godfrey Scale Category
X1.3	The presence of soil/peat causing settlement	0,750	Unacceptable
X2.1	Fluctuations in global steel prices under a lump-sum contract scheme	0,750	Unacceptable
X1.1	Drastic changes in weather conditions at the project site	0,563	Unacceptable
X2.3	ncreases in heavy equipment hire rates whilst the Contract is in force	0,563	Unacceptable
X2.4	Cost overruns for the mobilisation/demobilisation of heavy equipment	0,563	Unacceptable

➢ *In-Depth Root Cause Analysis*

Based on qualitative confirmation through in-depth interviews and visual observations with the project's technical management team, a root cause analysis was carried out for each risk indicator categorised as 'Unacceptable', as follows:

- Settlement of Foundation Structures Due to Peat Soil (X1.3, Index 0.750): This variable represents the highest critical risk in terms of both time delays and cost overruns. The root cause stems from the inherent geotechnical conditions of the peat soil in Palangka Raya, which exhibits high levels of consolidation and secondary settlement. The lack of accuracy in estimating the depth of the hard soil (final set) during the initial pile driving, combined with the absence of soil improvement measures beneath the warehouse floor slab, led to differential settlement of the foundations. This resulted in misalignment of the bolt joints in the steel portal frames and cracking of the concrete interior of the warehouse.
- Global Steel Price Fluctuations in Lump-Sum Contracts (X2.1, Index 0.750): The use of lump-sum (fixed-price) contracts shifts the entire risk of material price inflation to the contractor. The root of the problem lies in the uncertainty of the global steel market, which has surged sharply in the wake of the global energy crisis. Contractors who had locked in their initial tender prices found it difficult to cover the margin resulting from the rise in the price of imported WF/H-beam steel, leading them to temporarily delay placing orders with suppliers and triggering financial difficulties.
- Anomalies in Drastic Weather Changes (X1.1, Index 0.563): The Palangka Raya region frequently experiences sudden heavy downpours accompanied by strong winds. The root of the technical problem lies in the steel erection safety standards, which require the complete cessation of crane operations (mobile cranes/crawler cranes) when wind speeds exceed tolerance limits. Heavy rain also causes water to pool in the foundation excavation areas and accelerates the rate of corrosion on exposed steel joints that have not yet received their final coating.
- Burnout and Fatigue amongst Workers on Extreme Overtime (X6.1 & X6.4, Index 0.563): The work involved in joining and bolting wide-span steel portals is highly repetitive and carried out under exposure to scorching outdoor temperatures. The root cause stems from the implementation of a 'catch-up schedule' policy, involving marathon night-time and early-morning overtime shifts without a proportionate shift rota. These conditions lead to cumulative physical fatigue, reduce technical precision, and increase the rate of welding defects on site.
- Loss of Materials and Work Equipment (X8.1, Index 0.563): The extensive 30,000 m² material stockyard, which is not fully enclosed by a perimeter fence, is the primary root cause. The absence of sturdy temporary site fencing, combined with inadequate lighting levels (lux) and a lack of CCTV surveillance at night, creates opportunities for the theft of high-grade bolts, joint plates and electrical tools.
- Shortage of AWS-Certified Structural Welders (X4.1, Index 0.563): The fabrication of wide-span steel portal joints requires specially qualified welders. The root of the problem is the scarcity of local welders officially certified

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to American Welding Society (AWS) standards. Contractors forced to employ non-certified welders experience a high rate of defective welds with porosity when tested using Ultrasonic Testing (UT) by supervising consultants, necessitating time-consuming re-welding.

- Logistical Delays in Inter-Island Steel Shipments (X3.3, Index 0.563): The steel supply chain from manufacturers in Java to Palangka Raya involves sea transport followed by river transport. The root cause lies in the hydrological constraints of Kalimantan's river channels, where silting of navigation channels during the dry season hinders barges, or, conversely, high waves in the Java Sea during the rainy season delay the departure of Ro-Ro vessels and barges.
- Increase in Rental Rates and Heavy Equipment Mobilisation Costs (X2.3 & X2.4, Index 0.563): The installation of wide-span steel structures requires high-capacity lifting equipment (50–100-tonne cranes). The root of the problem lies in the absence of a long-term flat-rate rental agreement with local heavy equipment providers, compounded by local road load tonnage restrictions which force crane mobilisation routes to take lengthy detours, thereby inflating transport costs.

➢ *Formulation of a Structured Risk Mitigation Strategy and Expert Validation*

In order to address the root causes of all identified risks, a structured set of mitigation strategy recommendations was drawn up. This draft strategy was subsequently validated by three senior experts (a Senior Project Manager at PT Primatama, a Distribution Centre Specialist at PT SAT Tbk, and a Senior Project Manager at PT Rekajasa). All three experts agreed (100 per cent valid) that the detailed mitigation measures formulated were highly realistic, effective and practical for implementation in the field. A summary of the seven clusters of mitigation strategies, together with the experts' validation, is presented in Table 4.

Table 4 Clusters of Structured Risk Mitigation Strategy Recommendations and Expert Validation Results

No	Mitigation Strategy Cluster	Details of Key Mitigation Measures and Expert Validation
1	Weather Risk Anticipation & Management	Drawing up an implementation schedule that integrates BMKG climatological data; providing a covered steel fabrication workshop area on site to ensure assembly is not interrupted by sudden rain; and setting up a standby dewatering pump system in the foundation excavation area.
2	Technical Reinforcement & Site Management	Frequent deep boring geotechnical investigations at each main column grid to identify the location of hard soil; periodic settlement monitoring using a precision spirit level; 3D BIM modelling; and tiered welding quality inspections.
3	Strengthening Supply Chain Management	Implementation of medium-term fixed-price contracts with key steel suppliers; early ordering of steel (long-lead items) using a deposit system to lock in prices; maintenance of minimum stock levels for bolts and plates (20% buffer stock); and GPS tracking of maritime logistics.
4	Implementation of Rigorous Project	Management Control of the critical path using the Critical Path Method (CPM); weekly tripartite coordination meetings; use of a progress monitoring dashboard; an early warning system for delays; and accelerated verification of volume measurements to ensure smooth project milestones.
5	Workforce Skills Development	Official AWS-standard welder certification (porosity testing prior to installation); a maximum limit of 3 hours' night-time overtime under a two-shift system; provision of canteen facilities and vitamins; and the awarding of bonuses for achieving targets.
6	Strengthening Safety & Compliance (K3L)	Practical implementation of the Occupational Health, Safety and Environment Management System (SMKK); installation of steel lifelines on the roof portal frame as attachment points for body harnesses; PPE compliance checks; appointment of a Safety Officer; and 24-hour floodlighting of the stockyard.
7	Warehouse Operations & Commissioning	Loading tests on the concrete floor inside the warehouse prior to handover to ensure there is no subsequent ground subsidence; testing of utilities and the WMS; container manoeuvring simulations; and the installation of a fully enclosed perimeter fence.

IV. CONCLUSION

Based on the results of quantitative data analysis, bifactor EFA statistical testing, qualitative root-cause analysis, and the expert validation process for the Alfamart Warehouse Construction project in Palangka Raya, Central Kalimantan, the following comprehensive conclusions can be drawn:

- The mapping and analysis of risk acceptability based on the perceptions of 38 expert practitioners confirmed that the majority of the identified risk variables have a dominant influence on project implementation performance. In the dimension of project time delays, 41 variables (95.3 per cent) were identified as dominant risks (a combination of 7 'Unacceptable' and 34 'Undesirable' variables). Meanwhile, in the dimension of financial cost losses, 37 variables (86.0 per cent) were identified as dominant risks (a combination of 5 'Unacceptable' and 32 'Undesirable' variables).
- The highest-priority critical risk variables (classified as 'Unacceptable' with a Risk Index ≥ 0.563) that pose the greatest threat of project delays and cost overruns are driven by the following key factors: (a) the geotechnical characteristics of the local peat soil in Palangka Raya, which cause foundation settlement (with the highest risk

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index of 0.750); (b) fluctuations in global steel price spikes under a lump-sum contract scheme (index 0.750); (c) anomalous drastic changes in weather conditions, including heavy rainfall, at the project site (index 0.563); (d) increases in rental rates and cost overruns for the mobilisation of heavy-tonnage cranes (index 0.563); (e) work overload and cumulative physical fatigue amongst workers due to extreme night-time overtime (index 0.563); (f) the risk of loss of materials and tools in the stockyard area (index 0.563); (g) limited availability of AWS-certified structural welders (index 0.563); and (h) supply chain constraints in the delivery of steel from outside the island via the sea lanes and rivers of Kalimantan (index 0.563).

- Effective risk control measures, validated by senior experts, have been formulated into seven (7) clusters of structured mitigation strategies: (1) Anticipation and management of weather-related risks through the construction of enclosed site workshops and the provision of dewatering pumps; (2) Strengthening of Technical & Site Management through the implementation of dense deep boring at every column grid and regular settlement monitoring; (3) Strengthening of Supply Chain Management through fixed-price contracts and the early procurement of long-lead items; (4) Implementation of Rigorous Project Management based on the Critical Path Method (CPM) and a monitoring dashboard; (5) Enhancement of workforce competence and management through the use of AWS-certified welders and a limit on overtime to two shifts; (6) Strengthening of Health, Safety and Environmental (HSE) Compliance through the installation of steel lifelines and 24-hour stockyard lighting; and (7) Warehouse Operations and Commissioning through floor load testing prior to handover.

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