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Identify and Ranking Cost Overrun Factors in Military Construction Projects using FMEA

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ABSTRACT

Controlling and preventing cost overruns in defense construction projects remain a core, ongoing challenge for project managers. Due to the strategic significance of these endeavors and the numerous factors that drive cost increases in construction, extensive research has been conducted on this subject. Literature review indicates that the identification of cost overrun factors often relies solely on literature review and expert interviews. This research utilizes the Failure Mode and Effects Analysis (FMEA) technique, treating the identified causes of cost overrun as potential failure events. The identified factors are subsequently ranked using the Risk Priority Number (RPN) index. Finally, these factors are categorized, and corresponding risk response scenarios are proposed for their prevention or control. The resulting ranking clearly indicates that external macroeconomic shocks, specifically General Inflation (RPN=810) and Currency Exchange Volatility (RPN=729), represent the most significant threats due to their high inherent severity and difficulty of detection. This research thus provides a prioritized framework, demonstrating that effective cost management in this sector requires a strategic shift toward contractual and financial engineering to buffer against systemic instability, rather than focusing solely on internal project execution efficiencies.

1. INTRODUCTION

The construction sector is foundational to national economies globally, serving as both a major employer and a significant driver of investment. The development of a nation's infrastructure, which is directly managed by this industry, is a crucial prerequisite for achieving broader economic growth (Ashmita, 2019). Fundamentally, the construction industry operates by organizing and coordinating diverse resources, including personnel, equipment, materials, and capital, within a temporary organizational structure to meet specific targets (Abrar Husen, 2011). Furthermore, the presence of robust infrastructure is known to encourage equitable regional development (Nur Sahid, 2019).

Despite this significance, the sector contends with persistent issues that impede its success. Among these challenges, cost overruns represent the most significant obstacle reported across project lifecycles. Addressing this issue requires substantial attention from all stakeholders, as identifying the underlying causes is essential for improving cost efficiency. Prior research investigating factors that influence construction schedules consistently identifies the planning and implementation phases as the dominant source of project delays (Thapanont, 2018, Susanti 2023).

The fundamental objective is to enhance the productivity of defense construction projects while actively mitigating all forms of cost overruns. Consequently, the primary concern of project managers is identifying cost overrun factors, ranking them, and proposing prevention/control strategies. Accordingly, this research centers on a systematic approach for identifying the root causes of cost escalation, then employing a robust ranking mechanism to prioritize these causes, and finally, formulating concrete recommendations for proactive prevention and reactionary control measures. Following an initial literature review and factor

elicitation through expert interviews, this paper applies FMEA to systematically rank the identified factors. This prioritization enables a focused discussion on the most influential variables and outlines strategic managerial interventions.

2. LITERATURE REVIEW

Cost overruns represent a pervasive and financially significant challenge in the construction industry, with substantial impacts on project viability, stakeholder satisfaction, and overall economic efficiency. A wide body of research has identified numerous interrelated factors that contribute to these overruns.

Early studies highlight technical and planning-related deficiencies as primary drivers. Eri (2003) attributes cost overruns to incomplete design documentation, inaccurate supplier selection, errors in material cost estimation, delays in material delivery, volatile material prices, shifting economic conditions, and the introduction of additional scope or change orders. These issues often stem from inadequate upfront planning and poor risk anticipation during the pre-construction phase.

Human resource limitations also play a critical role. Yuanita (2003) observes that substandard supervisory competence—particularly among foremen—and delays in labor mobilization significantly contribute to budget deviations. Labor-related inefficiencies, including low productivity and absenteeism, further exacerbate cost pressures.

Equipment management represents another major source of waste. Wisnu (2003) identifies several equipment-related inefficiencies that can escalate costs, including inappropriate investment decisions, excessive rental expenses, mismatched equipment capacity, overutilization, premature equipment obsolescence, inadequate maintenance practices, improper repairs, frequent rework, and a high incidence of breakdowns requiring repair.

More recent studies expand the scope of contributing factors to include systemic and institutional challenges. Khanal and Ojha (2020) emphasize the influence of flawed procurement systems and political interference, while Ahwal et al. (2016) point to delayed payments for completed work, weak contract administration, the use of outdated or unsuitable construction methods, ineffective site supervision, poor communication among stakeholders, insufficient project management support, financial instability on the part of the client, regulatory constraints, and a shortage of skilled professionals.

Further corroborating these findings, Khanal and Ojha (2020), Ahwal et al. (2016), and Arjroody et al. (2023) collectively identify recurring operational and financial stressors including elevated labor costs, excessive overtime, labor absenteeism, project schedule delays, late payments by owners, and owners' financial constraints, as key contributors to cost overruns

Recent studies continue to expand the understanding of the multifaceted causes of cost overruns in construction projects. Arjroody et al. (2023) identify a broad range of material, labor, equipment, and finance related factors. These include frequent theft of construction materials, volatile and rising material prices, inappropriate material selection, improper storage leading to damage, inaccurate forecasting of market trends, and unplanned changes in required material quantities. On the labor front, the study notes that wage fluctuations, labor shortages, substandard workmanship, low productivity, and the misallocation of personnel significantly contribute to budget deviations. Equipment-related issues, such as high mobilization and demobilization expenses, poor organization of equipment storage, delays in equipment delivery, and the selection of unsuitable heavy machinery, further compound cost inefficiencies. Additionally, weak field-level cost control practices, delayed payment mechanisms, high interest rates on financing, insufficient financial capacity, and elevated equipment acquisition or rental costs are cited as critical financial drivers of overruns.

Complementing these findings, Abdelalim et al. (2025) emphasize deficiencies in the pre-construction phase as root causes of cost escalation. Specifically, they highlight inadequate initial budgeting, poor planning of material costs, inaccuracies in detailed quantity take-offs for both labor and materials, and the failure to account for inflation-driven increases in material prices.

Khanal and Ojha (2020) offer a more holistic perspective, framing cost overruns within a broader project ecosystem. They associate overruns with interrelated dimensions such as project implementation timelines, socio-cultural contexts, financial management, labor dynamics, accuracy of cost estimates, quality of planning documentation, organizational structure and staffing, on-site coordination and working relationships, field logistics, material availability, and adherence to the project schedule.

Collectively, these studies underscore that cost overruns are rarely attributable to a single cause; rather, they emerge from a confluence of planning gaps, operational inefficiencies, market volatility, and institutional or contextual constraints. Effective mitigation thus requires integrated strategies that address technical, human, financial, and managerial dimensions throughout the project lifecycle.

This study uses quantitative methods to analyze the factors that cause cost overruns on construction projects from the perspective of contractors and consultants. In general, this study is divided into 3 (Three) steps: Step (1) Identify critical factors driving cost overruns in defense construction by synthesizing findings from the literature, expert interviews, and empirical case studies, using Delphi process. Step (2) A structured questionnaire, based on the FMEA methodology, was administered to a panel of 30 subject matter experts, each possessing over several years of relevant experience in construction projects. Step (3) The most critical cost overrun factors in defense construction projects will be identified, and corresponding response scenarios will be developed for their mitigation.

The critical factors driving cost overruns in defense construction were synthesized from the literature review, expert interviews, and empirical case studies. These factors were then systematically organized into six distinct categories, as presented in Table 1.

Table 1. Critical factors causing cost overrun

No	Category	Variable Causes of Cost Overrun	Sources
1	External Factors	Rule changes	Abdelalim *et al*.(2025)
2		Socialization of land acquisition	Eliasson(2025), Abdelalim *et al.*(2025)
3		Land acquisition issues	Tayyab et al.(2023)
4		Public awareness about toll roads	Eliasson(2025), Abdelalim et al.(2025)
5		Unclear legal basis	Eliasson(2025), Abdelalim et al.(2025)
6		Soil condition	Abdelalim et al (2025)
7		Risks of natural change	Tayyab et al.(2023)
8		Labor strike	Abdelalim et al (2025)
9		Political intervention	Abdelalim et al (2025)
10		Conflict of ministries	Abdelalim et al (2025)
11		Project location	Abdelalim et al (2025)
12		Natural disasters	Tayyab et al.(2023)
13		Bad weather outside forecast	Tayyab et al.(2023)
14	Material Factors	Theft of materials	Zhu *et al.*(2021), Belay&Torp (2023)
15		An increase in material prices	Zhu et al.(2021), Belay&Torp (2023)
16		Material selection	Zhu et al.(2021), Belay&Torp (2023)
17		Errors in organizing material storage	Zhu et al.(2021), Belay&Torp (2023)
18		Material quantity change	Abdelalim et al (2025)
19		Less precise in predicting the market material prices	Susanti (2023)
20		Incomplete image design	Susanti (2023)
21		Less precise in determining the supplier	Susanti (2023)
22		Errors in the estimation of material costs	Susanti (2023)
23		Delay in material delivery	Kermanshachi (2023)
24		Project implementation delay	Khanal&Ojha(2020), Ahwal et al.(2016), Arjroody et al.(2023)
25		The presence of additional work	Susanti (2023)
26		Material prices fluctuate	Susanti (2023)
27		Poor material procurement	Susanti (2023)
28		Specification changes	Abdelalim et al (2025)
29	Labor Factors	Fluctuations in labor wages	Olaniran et al.(2015), Amini et al.(2023), Ankrah et al.(2023)
30		Labor shortage	Olaniran et al.(2015), Amini et al.(2023), Ankrah et al.(2023)
31		Poor Quality of Labor	Olaniran et al.(2015), Amini et al.(2023), Ankrah et al.(2023)
32		Labor productivity	Olaniran et al.(2015), Amini et al.(2023), Ankrah et al.(2023)
33		Less appropriate in the placement of personnel	Olaniran et al.(2015), Amini et al.(2023), Ankrah et al.(2023)
34		Planning and making schedules	Yuanita.S (2003)
35		High cost of work	Khanal&Ojha(2020), Ahwal et al.(2016), Arjroody et al.(2023)
36		Labor productivity	Khanal&Ojha(2020), Ahwal et al.(2016), Arjroody et al.(2023)
37		Poor quality Foreman	Yuanita.S (2003)
38		Delay in the Provision of Labor	Yuanita.S (2003)
39		Heavy overtime / Overtime	Kermanshachi (2023), Khanal&Ojha(2020), Ahwal et al.(2016), Arjroody et al.(2023)
40		Limited human resources	Adepu et al.(2024), Ahwal et al.(2016), Arjroody et al.(2023)
41		Labor absenteeism	Adepu et al.(2024)
42		High price/rental of equipment	Zhu et al.(2021), Belay&Torp (2023)

No	Category	Variable Causes of Cost Overrun	Sources
43		High equipment mobilization/demobilization costs	Zhu et al.(2021), Belay&Torp (2023)
44		Late delivery of equipment	Zhu et al.(2021), Belay&Torp (2023), Kermanshachi (2023)
45		Machine selection	Zhu et al.(2021), Belay&Torp (2023)
46		Errors in organizing equipment storage	Zhu et al.(2021), Belay&Torp (2023)
47		Errors in equipment investment	Isfahani et al.(2023), Khanal&Ojha(2020), Ahwal et al.(2016)
48		The high cost of rent	Isfahani et al.(2023), Khanal&Ojha(2020), Ahwal et al.(2016)
49	**Equipment Factors**	Tool capacity does not match	Isfahani et al.(2023), Khanal&Ojha(2020), Ahwal et al.(2016)
50		The tool works too heavy	Isfahani et al.(2023), Khanal&Ojha(2020), Ahwal et al.(2016)
51		The low economic life of the equipment	Isfahani et al.(2023), Khanal&Ojha(2020), Ahwal et al.(2016)
52		Poor tool maintenance	Isfahani et al.(2023), Khanal&Ojha(2020), Ahwal et al.(2016)
53		Repair of unsuitable tools	Isfahani et al.(2023), Khanal&Ojha(2020), Ahwal et al.(2016)
54		Change of job/rework	Isfahani et al.(2023), Khanal&Ojha(2020), Ahwal et al.(2016)
55		Limited funding sources	Isfahani et al.(2023), Khanal&Ojha(2020), Ahwal et al.(2016)
56		Equipment availability	Isfahani et al.(2023), Khanal&Ojha(2020), Ahwal et al.(2016)
57		High frequency of tool repair	Isfahani et al.(2023), Khanal&Ojha(2020), Ahwal et al.(2016)
58		Less experienced contractors	Youssefi&Celik (2023)
59		Unprofitable contracts	Youssefi&Celik (2023)
60		Poor supervision of construction projects	Youssefi&Celik (2023)
61		Errors in predicting field conditions	Youssefi&Celik (2023)
62		Low productivity	Isfahani et al.(2023), Khanal&Ojha(2020), Ahwal et al.(2016)
63		Lack of contractor experience	Isfahani et al.(2023), Khanal&Ojha(2020), Ahwal et al.(2016)
64		Lack of coordination (contractors)	Isfahani et al.(2023), Khanal&Ojha(2020), Ahwal et al.(2016)
65		Slow payment for completed work	Kansal&Agarwal (2022), Ma et al.(2024)
66	**Subcontractor Factors**	Poor contract management	Kansal&Agarwal (2022), Ma et al.(2024), Abdelalim et al (2025)
67		Outdated or unsuitable construction methods	Kansal&Agarwal (2022), Ma et al.(2024), Abdelalim et al (2025)
68		Poor site management and supervision	Kansal&Agarwal (2022), Ma et al.(2024), Abdelalim et al (2025)
69		Slow flow of information between parties	Kansal&Agarwal (2022), Ma et al.(2024), Abdelalim et al (2025)
70		Poor project management help	Kansal&Agarwal (2022), Ma et al.(2024), Abdelalim et al (2025)
71		Owner's financial difficulties	Kansal&Agarwal (2022), Ma et al.(2024), Abdelalim et al (2025)
72		Obstacles from the government	Kansal&Agarwal (2022), Ma et al.(2024), Abdelalim et al (2025)
73		Lack of expert power	Kansal&Agarwal (2022), Ma et al.(2024), Abdelalim et al (2025)
74		Financial difficulties of the contractor	Hong Anh Vu(2016)
75		Inflation	Abdelalim et al (2025)
76		Currency exchange rate changes	Abdelalim et al (2025)
77		Changes in economic conditions	Susanti (2023)
78		Tax increase	Abdelalim et al (2025)
79		Poor cost control in the field	Zhu et al.(2021), Belay&Torp (2023)
80	**Finance Factors**	Untimely payment method	Zhu et al.(2021), Belay&Torp (2023)
81		High-interest rates on bank loans	Zhu et al.(2021), Belay&Torp (2023)
82		Lack of funding/financial capability	Zhu et al.(2021), Belay&Torp (2023)
83		Poor financial control	Khanal&Ojha(2020), Ahwal et al.(2016), Arjroody et al.(2023)
84		late payment by the owner	Khanal&Ojha(2020), Ahwal et al.(2016), Arjroody et al.(2023)
85		financial difficulties of the owner	Khanal&Ojha(2020), Ahwal et al.(2016), Arjroody et al.(2023)

3. RESEARCH METHODOLOGY

FMEA is an analytical technique that tries to identify and rank the potential risks, in the desired risk-assessment range, and find their related causes and effects. It is a method that predicts breakdowns, defects, and deficiencies probable in the design of a product or in its production process; hence, it prevents such problems and reduces related costs. First, it was officially introduced in the US in the late 1940s for military purposes, then Ford Co. introduced it in the automobile industry in the late 1970s and today it is widely used in various industries. The steps of this technique are shown in Figure 1.

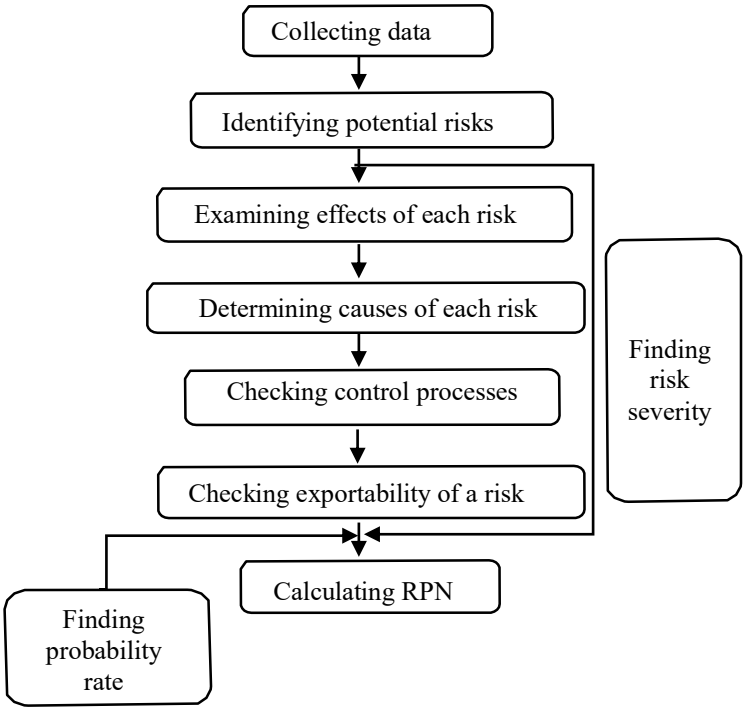

Figure 1. Hierarchy in FMEA method (AIAG, 2008)

RPN (risk priority number) is a product of S (severity), O (occurrence probability) and D (detection probability).

RPN= S * O * D Eq. (1)

Now, risks are ranked based on their priority numbers limited by the FMEA system (AIAG, 2008). Severity, occurrence probability and detection probability of risks are determined as following sections.

3.1. Risk Severity

Risk severity means its "effect" and its quantitative indices are scaled from 1 to 10 (Table 2).

3.2. Occurrence Probability

Occurrence probability determines the frequency of the cause/mechanism of a potential risk and Table 3 helps specify this probability on a 1-10 scale. Reviewing past records/documents, control processes, standards, work rules/requirements and how they are used can help reach this number (AIAG, 2008).

Table 2. Risk severity

Rank	Severity
10	No alarming
9	Alarming
8	Very high
7	High
6	Average
5	Low
4	Very low
3	Low
2	Almost none
1	None

Table 3. Risk occurrence probability

Rank	Occurrence probability
10	Quite high – almost unavoidable
8	High - repetitive risks
6	Average
3	Low
1	Improbable - unlikely

3.3. Detection Probability

Risk detection probability rate (Table 4) helps detect risks before they occur and examining the standards control, processes requirements / rules and how they are applied can highly help reach this number (AIAG, 2008).

Table 4. Risk detection probability

Rank	Detectability
10	Absolutely none
9	Very low
8	Low
7	Very low
6	Low
5	Average
4	Relatively high
3	High
2	very high
1	Almost certain

4. FUNDINGS

From the results of descriptive analysis to obtain the dominant factor in SPSS program statistics. get the results in the form of Severity, Occurrence, Detection and RPN in Table 5.

Table 5. Result in FMEA Analysis of Cost Overrun Factors

Factor Category	Factor	Severity (S) (Est.)	Occurrence (O) (Est.)	Detection (D) (Est.)	RPN (S×O×D)	Rank
Factor External	Rule changes	8	9	8	576	3
	Socialization of land acquisition	8	7	6	336	14
	Land acquisition issues	8	8	7	448	9
	Public awareness about toll roads	5	4	5	100	43
	Unclear legal basis	8	8	8	512	6
	Soil condition	7	6	3	126	37
	Risks of natural change	7	3	3	63	47
	Labor strike	8	3	4	96	44
	Political intervention	9	8	9	648	1
	Conflict of ministries	9	7	9	567	4
	Project location	6	5	4	120	39
	Natural disasters	9	2	6	108	41
	Bad weather outside forecast	6	4	5	120	38
Factor Material	Theft of materials	7	5	5	175	34
	An increase in material prices	9	10	9	810	2
	Material selection	6	4	5	120	36
	Errors in organizing material storage	5	6	4	120	35
	Material quantity change	7	5	6	210	29
	Less precise in predicting the market	8	9	8	576	2
	Incomplete image design	8	6	7	336	15
	Less precise in determining the supplier	7	7	7	343	12
	Errors in the estimation of material costs	7	8	6	336	16
	Delay in material delivery	8	8	7	448	8

Factor Category	Factor	Severity (S) (Est.)	Occurrence (O) (Est.)	Detection (D) (Est.)	RPN (S×O×D)	Rank
	Project implementation delay	9	7	7	441	10
	The presence of additional work	8	7	6	336	17
	Material prices fluctuate	9	10	9	810	2
	Poor material procurement	7	7	7	343	11
	Specification changes	8	6	7	336	18
Factor Labor	Fluctuations in labor wages	8	9	8	576	5
	Labor shortage	8	7	7	392	19
	Poor Quality of Labor	7	6	5	210	28
	Labor productivity	6	7	5	210	27
	Less appropriate in the placement of	6	5	5	150	32
	Planning and making schedules	7	6	6	252	25
	High cost of work	8	8	7	448	7
	Labor productivity (Duplicate)	6	7	5	210	26
	Poor quality Foreman	7	5	6	210	30
	Delay in the Provision of Labor	7	6	7	294	22
	Heavy overtime / Overtime	7	6	5	210	31
	Limited human resources	7	6	6	252	24
	Labor absenteeism	5	5	4	100	42
Factor Equipment	High price/rental of equipment	8	8	7	448	10
	High equipment	7	7	6	294	21
	Late delivery of equipment	7	7	7	343	13
	Machine selection	6	5	5	150	33
	Errors in organizing equipment storage	5	5	4	100	45
	Errors in equipment investment	7	5	6	210	28
	The high cost of rent (Duplicate)	8	8	7	448	11
	Tool capacity does not match	7	5	6	210	28
	The tool works too heavy	6	4	5	120	40
	The low economic life of the equipment	7	5	6	210	28
	Poor tool maintenance	7	6	5	210	28
	Repair of unsuitable tools	7	5	6	210	28
	Change of job/rework	8	7	7	392	20
	Limited funding sources	9	7	8	504	7
	Equipment availability	7	5	5	175	34
	High frequency of tool repair	7	6	5	210	28
Factor Subcontractor	Less experienced contractors	8	7	7	392	23
	Unprofitable contracts	8	8	7	448	12
	Poor supervision of construction projects	7	8	7	392	23
	Errors in predicting field conditions	7	7	6	294	20
	Low productivity	7	7	6	294	20
	Lack of contractor experience	8	7	7	392	23
	Lack of coordination (contractors)	7	7	6	294	20
	Slow payment for completed work	8	6	7	336	19
	Poor contract management	7	7	8	392	23
	Outdated or unsuitable construction	6	6	5	180	33
	Poor site management and supervision	8	7	7	392	23
	Slow flow of information between parties	7	7	6	294	20
	Poor project management help	8	7	7	392	23
	Owner's financial difficulties	9	6	8	432	13
	Obstacles from the government	9	8	9	648	1
	Lack of expert power	7	6	5	210	28
	Financial difficulties of the contractor	9	7	8	504	8
Factor Finance	Inflation	9	10	9	810	2
	Currency exchange rate changes	9	9	9	729	3
	Changes in economic conditions	9	9	8	648	5
	Tax increase	8	6	7	336	15

Factor Category	Factor	Severity (S) (Est.)	Occurrence (O) (Est.)	Detection (D) (Est.)	RPN (S×O×D)	Rank
	Poor cost control in the field	7	7	5	245	26
	Untimely payment method	7	6	6	252	25
	High-interest rates on bank loans	8	7	7	392	23
	Lack of funding/financial capability	9	7	8	504	7
	Poor financial control	7	6	5	210	28
	late payment by the owner	8	7	7	392	23
	financial difficulties of the owner	9	6	8	432	13

Based on the high-risk assumptions for military construction projects, the factors that require the most immediate attention (highest estimated RPN) are selected and categorized as Table 6.

Table 6. Rank of Cost Overrun Factors using FMEA Analysis

Rank (by Avg. RPN)	Categorized Risk Area	Contributing Factors (Original)	Severity (S)	Occurrence (O)	Detection (D)	RPN
1	General Inflation and Material Price Escalation	Inflation	9	10	9	810
1		An increase in material prices; Material prices fluctuate	9	10	9	810
2	Currency Exchange Volatility	Currency exchange rate changes	9	9	9	729
3	Governmental/Political Interference	Political intervention; Conflict of ministries	9/9	8/7	9/9	648 / 567
4	Subcontractor Government Obstacles	Obstacles from the government (Subcontractor)	9	8	9	648
5	Regulatory & Rule Changes	Rule changes	8	9	8	576
	Labor Wage Fluctuation	Fluctuations in labor wages	8	9	8	576
	Material Market Uncertainty	Less precise in predicting the market (Material)	8	9	8	576
6	Subcontractor Financial Instability	Financial difficulties of the contractor	9	7	8	504
7	Legal/Contractual Ambiguity	Unclear legal basis	8	8	8	512
8	Owner/Client Financial Risk	Owner's financial difficulties (Combined)	9	6	8	432
9	Project Timeline Delays	Project implementation delay	9	7	7	441
10	High Unit Cost of Work	High cost of work (Labor)	8	8	7	448
	Unprofitable Subcontracts	Unprofitable contracts	8	8	7	448
11	Equipment Cost/Rental	High price/rental of equipment; The high cost of rent	8	8	7	448
12	Material Delivery Delays	Delay in material delivery	8	8	7	448
13	Land Acquisition Issues	Land acquisition issues	8	8	7	448

The primary focus for mitigation efforts must be on Economic Risk Mitigation (Rank 1 & 2) through hedging strategies, robust escalation clauses in contracts, and securing long-term material pricing agreements where possible.

The secondary focus should be on Government Interface and Subcontractor Management (Rank 3, 4, 6). Since the detection scores (D) for the top risks are generally high (meaning they are hard to detect once started), proactive risk monitoring, contingency planning, and robust contractual vetting processes are essential controls to drive down the RPNscores in future iterations.

Using expert consultation, proposed responses targeting the highest-priority cost-increasing factors were suggested. The top recommendations are presented in **Table 7**. These proposals are segregated into their respective columns based on whether they primarily improve Severity (S), Occurrence (O), or Detectability (D).

Risk responses can adhere to one of four general strategies: 1. Risk Acceptance, 2. Risk Mitigation, 3. Risk Transfer, or 4. Risk Avoidance. Project Management Institute (2021)

In this table, the impact of each action on RPNreduction is calculated as a percentage, the required resources are quantified on a 1-to-9 Likert scale, and the desirability rating (or Adjusted Efficiency Index, AEI) for each response scenario is calculated by dividing the RPNimprovement percentage by the required resources and normalizing the result to a scale of 1 to 100."

Table 7. Proposed Actions to Cost Overrun Factors and their Adjusted Efficiency Index (AEI)

Rank	Risk Category	Action for Severity (S) (Resources, RPN Improvement %, AEI)	Action for Occurrence (O) (Resources, RPN Improvement %, AEI)	Action for Detection (D) (Resources, RPN Improvement %, AEI)
1	**General Inflation** (RPN = 810)	Implement an **Escalation Clause** in the contract for inflation rate adjustment. 7, 10%, 14.28	Negotiate fixed exchange rates for predictable international cost components. 8, 10%, 12.5	Launch a weekly dashboard monitoring official inflation indices and contractor inflation forecasts. 7, 5%, 5.0
	Material Price Increase (RPN = 810)	Set a **Price Cap** for key materials within contracts. 8, 15%, 18.75	Secure long-term guaranteed purchase agreements with strategic suppliers. 9, 20%, 22.22	Establish a **Buffer Stock** for critical materials. 8, 10%, 12.5
2	**Exchange Rate Volatility** (RPN = 729)	Transfer volatility risk via **Futures/Forwards contracts** or insurance. 8, 12%, 15.0	Set a fixed reference exchange rate for international payment calculations. 7, 15%, 21.42	Daily reporting on exchange rate fluctuations and their impact on project cash flow. 8, 3%, 3.75
3	**Political/Government Intervention** (RPN ≈ 600)	Form a high-authority stakeholder management team for immediate issue resolution. 9, 15%, 16.66	Designate a formal, fixed communication channel with key decision-making bodies. 9, 20%, 22.22	Conduct regular quarterly meetings with senior officials for strategic alignment. 9, 5%, 5.55
4	**Contractor Governmental Barriers** (RPN = 648)	Guarantee direct payment to subcontractors if the Employer causes delays. 6, 10%, 16.66	Develop a comprehensive checklist for permit prerequisites *before* work commencement. 6, 15%, 25.0	Assign a dedicated expert to exclusively track permit files within government agencies. 6, 5%, 8.33
5	**Regulation Change** (RPN = 576)	Reduce the scope of work heavily impacted by unstable regulations (Partial Avoidance). 4, 10%, **25.0**	Actively participate in standards drafting committees to anticipate future changes. 4, 10%, **25.0**	Conduct periodic (monthly) legal audits by a specialized consultant on new legislation. 4, 5%, 12.5
	Labor Wage Fluctuation (RPN = 576)	Utilize multi-skilled labor and high trainability (reducing reliance on expensive specialists). 5, 5%, 10.0	Sign labor supply contracts with a clearly defined minimum annual increase. 5, 10%, 20.0	Create an internal index to track the average regional wage rate. 5, 5%, 10.0
6	**Contractor Financial Instability** (RPN = 504)	Require strong bank guarantees or use contractor receivables insurance. 7, 15%, 21.42	Re-evaluate the financial health of key contractors after every payment milestone. 7, 20%, 28.57	Implement a contractor financial rating system with quarterly updates. 7, 10%, 14.28

Rank	Risk Category	Action for Severity (S) (Resources, RPN Improvement %, AEI)	Action for Occurrence (O) (Resources, RPN Improvement %, AEI)	Action for Detection (D) (Resources, RPN Improvement %, AEI)
7	**Contractual/Legal Ambiguity** (RPN = 512)	Enforce transparent contract standards (e.g., using advanced reference contracts). 6, 20%, **33.33**	Conduct a comprehensive legal review by two independent legal teams before signing. 6, 20%, **33.33**	Create a "Contractual Decision Matrix" to resolve ambiguities during execution. 6, 10%, 16.66
8	**Employer Financial Risk** (RPN = 432)	Transfer risk via guaranteed advance payments or independent Letters of Credit. 6, 15%, 25.0	Mandate the employer to create an **Escrow Account** for essential expenses. 6, 20%, **33.33**	Monitor the employer's quarterly financial reports via an independent project auditor. 6, 5%, 8.33
9	**Schedule Delay** (RPN = 441)	Impose heavy delay penalties in contracts to maintain party motivation. 5, 10%, 20.0	Implement Critical Chain Project Management (CCPM) for schedule buffering. 5, 15%, **30.0**	Use project management systems with daily progress reporting and real-time dashboards. 5, 5%, 10.0
10	**High Unit Labor Cost** (RPN = 448)	Employ modern construction technologies (e.g., modular) to reduce direct costs. 4, 10%, **25.0**	Run competitive tenders for all major work units based on actual cost standards. 4, 5%, 12.5	Conduct performance audits of unit labor costs using data from similar projects. 4, 5%, 12.5
11	**Equipment Cost/Rental** (RPN = 448)	Prefer renting equipment as needed over purchasing heavy machinery. 3, 5%, **16.66**	Create a database of available regional equipment capacity for optimal utilization. 3, 10%, **33.33**	Monitor actual equipment usage (operating hours) against rental invoices. 3, 5%, 16.66
12	**Material Delivery Delay** (RPN = 448)	Increase delay penalties for key suppliers. 5, 5%, 10.0	Contract with at least two approved suppliers for every critical material (Dual Sourcing). 5, 15%, **30.0**	Utilize GPS/IoT tracking for real-time monitoring of material transport. 5, 5%, 10.0
13	**Land Acquisition Issues** (RPN = 448)	Select alternative sites during the initial planning phases. 6, 5%, 8.33	Start the land acquisition assessment and negotiation process immediately after the feasibility study. 6, 10%, 16.66	Set a strict timeline for land acquisition phases with weekly reporting. 6, 5%, 8.33

5. DISCUSSION AND CONCLUSION

The Failure Modes and Effects Analysis (FMEA) executed on cost overrun factors in military construction projects highlights a clear stratification of risk, where **external, macroeconomic instability** overwhelms internal operational controls. The consolidated RPNranking (detailed in the preceding table) pinpoints several high-priority areas that demand strategic mitigation rather than mere operational oversight.

The 15 consolidated risk areas can be grouped into three primary root cause clusters, which collectively explain the highest RPNvalues:

Cluster A: Macroeconomic and Financial Systemic Shocks (Highest RPN)

This cluster represents the most critical threat, exemplified by **General Inflation** (RPN = 810) and **Material Price Escalation** (RPN = 810).

- **Root Cause:** These risks are primarily driven by **systemic, non-project-specific economic policies and global market dynamics.** In the context of long-term military construction contracts, the primary failure lies in the **inadequate contractual frameworks** that fail to adequately account for high volatility (O = 10). The high Severity (S = 9) confirms that once these events occur, the financial impact on the project budget is near-total.

- **Mitigation Implication:** The high RPNhere stems from the difficulty in **Detection** (D = 9), indicating that standard project cost tracking is insufficient. Mitigation requires legislative or contractual mechanisms, such as inflation indexing or stabilization funds, rather than site-level controls.

Cluster B: Governance, Bureaucracy, and Interface Risk

This cluster, featuring **Governmental/Political Interference** (RPN ≈ 648) and **Subcontractor Government Obstacles** (RPN = 648), points to institutional friction as a major risk amplifier.

- **Root Cause:** The root lies in the **complexity and frequent regulatory turnover inherent in the public sector.** Military projects, by nature of their security classification and inter-ministerial involvement, are highly susceptible to administrative delays and re-prioritization. This friction directly increases both the likelihood (O) and the severity (S) of operational disruptions, such as material delays or subcontracting issues.
- **Mitigation Implication:** Addressing these requires **improving cross-agency communication protocols** and establishing clear, non-negotiable service-level agreements (SLAs) with regulatory bodies upfront in the contract lifecycle.

Cluster C: Operational Vulnerabilities and Cost Structure

This cluster encompasses inherent project management weaknesses related to inputs: **Labor Wage Fluctuation** (RPN = 576), **Equipment Cost** (RPN = 448), and **Subcontractor Financial Instability** (RPN = 504).

- **Root Cause:** These risks are rooted in the **inaccurate initial cost estimation and poor supply chain resilience.** Specifically, the failure to accurately forecast labor market tightness or secure reliable, financially sound downstream partners (subcontractors) leads to these factors materializing when market conditions are unfavorable.
- Mitigation Implication: The relatively better D scores (though still high) suggest that enhanced pre-qualification, rigorous due diligence on subcontractor balance sheets, and market intelligence gathering can offer meaningful control points to reduce the overall RPN.

Based on the root cause analysis, two critical areas for management proposals and future research emerge. Management should prioritize the formalization of Economic Hedging Strategies across all large-scale contracts to address the top-ranked risks (Inflation and Material Escalation). This involves mandating the inclusion of indexed escalation clauses tied to recognized national economic indicators, as well as establishing escrow accounts or guaranteed maximum price (GMP) contracts with key material suppliers. Furthermore, to combat bureaucratic friction (Cluster B), project charters must include a dedicated Inter-Agency Liaison Officer whose sole function is to proactively clear regulatory and ministerial roadblocks, thus focusing on lowering the Detection (D) scores associated with governmental obstacles.

Future academic investigation should focus on developing a Predictive Volatility Index (PVI) tailored for defense construction procurement. This index would integrate macroeconomic indicators (Cluster A) with political stability metrics (Cluster B) to generate a quantifiable, dynamic risk score that updates quarterly, allowing contracting officers to adjust contingency budgets more accurately than static historical data permits. Furthermore, research should explore the impact of Digital Twin/BIM integration on the Detection (D) scores for physical risks like supply chain delays, determining if enhanced real-time visibility can significantly break the high correlation currently observed between S, O, and Dfor operational factors.

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