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A Hybrid FMEA-DEMATEL Approach to Uncover Root Causes of Cost Overruns in Military Construction Projects

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Abstract

Controlling and preventing cost overruns in defense construction projects remains a persistent and high-stakes challenge for construction project managers in defense agencies alike. Given the strategic importance of these projects and the complex web of interrelated risk factors, this study advances beyond conventional approaches by integrating Failure Mode and Effects Analysis (FMEA) with the DEMATEL (Decision-Making Trial and Evaluation Laboratory) method. Initially, 85 distinct cost overrun factors were identified from literature and expert input, each assessed via FMEA to compute a Risk Priority Number (RPN). The top-ranked threats included General Inflation (RPN = 810) and Exchange Rate Volatility (RPN = 729), reflecting their high severity and low detectability. To manage complexity, based experts' judgment, these factors were systematically consolidated into 18 representative categories spanning external, material, labor, equipment, subcontractor, and financial domains. A DEMATEL analysis was then applied to model causal relationships among these categories. The results reveal that political and bureaucratic interference, owner-side financial instability, and macroeconomic shocks function as the primary root causes, exerting strong net influence on downstream effects such as design changes, material delays, and schedule slippage. In contrast, many commonly managed symptoms (e.g., labor productivity or material theft) are largely consequences of these upstream drivers. This study thus proposes a dual-layer risk response framework: Strategic-level interventions, including inflation-indexed contracts, inter-ministerial coordination, and dedicated defense construction financing and tactical controls targeting high-prominence effects. The findings advocate for a paradigm shift in defense project management: from reactive cost containment to proactive systemic risk governance, where financial and institutional resilience becomes as critical as on-site execution efficiency.

***Keywords:** Cost Overrun, Construction Project, FMEA, DEMATEL, Military projects.*

1. **Strategic Focus:**
   "Governance Over Gear: How Political and Financial Instability Drive Cost Overruns in Defense Infrastructure"
2. **Methodological Focus:**
   "Integrating FMEA and DEMATEL for Causal Risk Analysis of Cost Overruns in Strategic Construction Projects"
3. **Policy/Practical Focus:**
   "From Reactive Control to Proactive Resilience: Rethinking Cost Management in Military Construction"
4. **Concise & Academic:**
   "Root Cause Analysis of Cost Overruns in Defense Construction: A Hybrid FMEA–DEMATEL Framework"
5. **Emphasizing Macroeconomic Risk:**
   "When Inflation Isn't the Enemy: Unmasking True Drivers of Cost Overruns in Military Infrastructure Projects"

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) Finding root cause factors by studying causal effect among important cost overrun factors using DEMATEL. Step (4) As results, the most causal cost overrun factors in defense construction projects will be identified, and corresponding response scenarios will be developed for their mitigation.

3. Research Methodology

This research has two major steps. First, ranking and categorizing the most important cost overrun factors in construction project based FMEA. Then, studying causal effects among them using DEMATEL.

3.1. Determining cost overrun factors

The critical factors driving cost overruns in defense construction were synthesized from the literature review, expert interviews, and empirical case studies.

3.2. Ranking cost overrun factors based FMEA

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.

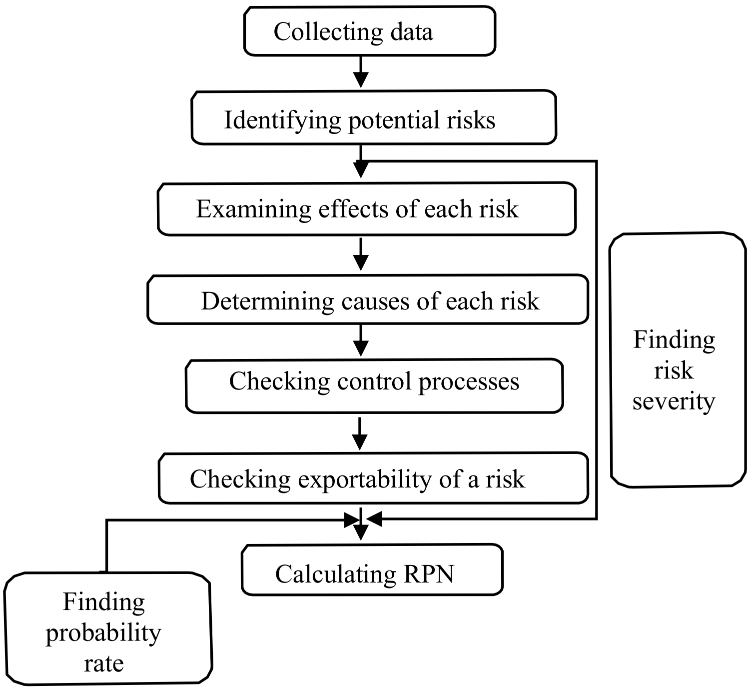


***Figure** 1. Hierarchy in FMEA method (AIAG, 2008)*

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.

3.3. Causal effects among cost overrun factors based DEMATEL

The DEMATEL (Decision-Making Trial and Evaluation Laboratory) method is a structured multi-criteria decision-making (MCDM) technique developed by the Battelle Memorial Institute in the 1970s to model and analyze complex cause–effect relationships among elements in a system (Fontela & Gabus, 1976). It is particularly effective in identifying interdependencies among factors, distinguishing between *causal* (driver) and *effect* (dependent) elements, and visualizing systemic structures through a causal diagram, Table 1.

In a proper analysis, Experts must provide pairwise influence scores (typically on a 0–4 scale) indicating how strongly each factor *i* influences factor *j*. The initial direct-relation matrix (A) must be filled using domain knowledge or survey data.

Table 1. *DEMATEL matrices*

Matrix	Full Name	Role in DEMATEL
A	Initial Direct-Relation Matrix	A square matrix where each entry a_{ij} represents the direct influence (e.g., 0–4 scale) of factor *i* on factor *j*, typically based on expert judgments.
D	Normalized Direct-Relation Matrix	Obtained by normalizing **A** using the maximum row sum: $D = A/k$, where $k = \max\left(\sum_j a_{ij}\right)$. Ensures convergence of the total relation matrix.
T	Total Relation Matrix	Represents the full (direct + indirect) influences among factors: $T = D(I - D)^{-1}$. Each entry t_{ij} shows the total influence of factor *i* on factor *j*.

DEMATEL begins with constructing a direct-relation matrix based on expert judgments, representing the pairwise influence strength between factors. This matrix is then normalized and used to compute a total-relation matrix, which captures both direct and indirect influences. From this, two key metrics are derived:

- Prominence (d + r): the overall importance of a factor,
- Relation (d – r): whether a factor acts primarily as a cause (positive value) or an effect (negative value).

The method is widely applied in risk management, sustainability, supply chain, and construction project analysis—especially for identifying root causes of issues like cost overruns, delays, or safety failures, Tavana et al., 2016; Govindan et al., 2015).

4. Fundings

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 2.

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 2.

Table 2*. Critical factors causing cost overrun determined using Delphi method and ranked by FMEA*

No	Category	Variable Causes of Cost Overrun	Sources	RPN (S×O× D)	Rank
1	External Factors	Rule changes	Abdelalim *et al.*(2025)	576	3
2		Socialization of land acquisition	Eliasson(2025), Abdelalim *et al.*(2025)	336	14
3		Land acquisition issues	Tayyab et al.(2023)	448	9
4		Public awareness about toll roads	Eliasson(2025), Abdelalim et al.(2025)	100	43

No	Category	Variable Causes of Cost Overrun	Sources	RPN (S×O×D)	Rank
5		Unclear legal basis	Eliasson(2025), Abdelalim et al.(2025)	512	6
6		Soil condition	Abdelalim et al (2025)	126	37
7		Risks of natural change	Tayyab et al.(2023)	63	47
8		Labor strike	Abdelalim et al (2025)	96	44
9		Political intervention	Abdelalim et al (2025)	648	1
10		Conflict of ministries	Abdelalim et al (2025)	567	4
11		Project location	Abdelalim et al (2025)	120	39
12		Natural disasters	Tayyab et al.(2023)	108	41
13		Bad weather outside forecast	Tayyab et al.(2023)	120	38
14	**Material Factors**	Theft of materials	Zhu *et al.*(2021), Belay&Torp (2023)	175	34
15		An increase in material prices	Zhu et al.(2021), Belay&Torp (2023)	810	2
16		Material selection	Zhu et al.(2021), Belay&Torp (2023)	120	36
17		Errors in organizing material storage	Zhu et al.(2021), Belay&Torp (2023)	120	35
18		Material quantity change	Abdelalim et al (2025)	210	29
19		Less precise in predicting the market material prices	Susanti (2023)	576	2
20		Incomplete image design	Susanti (2023)	336	15
21		Less precise in determining the supplier	Susanti (2023)	343	12
22		Errors in the estimation of material costs	Susanti (2023)	336	16
23		Delay in material delivery	Kermanshachi (2023)	448	8
24		Project implementation delay	Khanal&Ojha(2020), Ahwal et al.(2016), Arjroody et al.(2023)	441	10
25		The presence of additional work	Susanti (2023)	336	17
26		Material prices fluctuate	Susanti (2023)	810	2
27		Poor material procurement	Susanti (2023)	343	11
28		Specification changes	Abdelalim et al (2025)	336	18
29	**Labor Factors**	Fluctuations in labor wages	Olaniran et al.(2015), Amini et al.(2023), Ankrah et al.(2023)	576	5
30		Labor shortage	Olaniran et al.(2015), Amini et al.(2023), Ankrah et al.(2023)	392	19
31		Poor Quality of Labor	Olaniran et al.(2015), Amini et al.(2023), Ankrah et al.(2023)	210	28
32		Labor productivity	Olaniran et al.(2015), Amini et al.(2023), Ankrah et al.(2023)	210	27
33		Less appropriate in the placement of personnel	Olaniran et al.(2015), Amini et al.(2023), Ankrah et al.(2023)	150	32
34		Planning and making schedules	Yuanita.S (2003)	252	25
35		High cost of work	Khanal&Ojha(2020), Ahwal et al.(2016), Arjroody et al.(2023)	448	7
36		Labor productivity	Khanal&Ojha(2020), Ahwal et al.(2016), Arjroody et al.(2023)	210	26
37		Poor quality Foreman	Yuanita.S (2003)	210	30
38		Delay in the Provision of Labor	Yuanita.S (2003)	294	22

No	Category	Variable Causes of Cost Overrun	Sources	RPN (S×O×D)	Rank
39		Heavy overtime / Overtime	Kermanshachi (2023), Khanal&Ojha(2020), Ahwal et al.(2016), Arjroody et al.(2023)	210	31
40		Limited human resources	Adepu et al.(2024), Ahwal et al.(2016), Arjroody et al.(2023)	252	24
41		Labor absenteeism	Adepu et al.(2024)	100	42
42	Equipment Factors	High price/rental of equipment	Zhu et al.(2021), Belay&Torp (2023)	448	10
43		High equipment mobilization/demobilization costs	Zhu et al.(2021), Belay&Torp (2023)	294	21
44		Late delivery of equipment	Zhu et al.(2021), Belay&Torp (2023), Kermanshachi (2023)	343	13
45		Machine selection	Zhu et al.(2021), Belay&Torp (2023)	150	33
46		Errors in organizing equipment storage	Zhu et al.(2021), Belay&Torp (2023)	100	45
47		Errors in equipment investment	Isfahani et al.(2023), Khanal&Ojha(2020), Ahwal et al.(2016)	210	28
48		The high cost of rent	Isfahani et al.(2023), Khanal&Ojha(2020), Ahwal et al.(2016)	448	11
49		Tool capacity does not match	Isfahani et al.(2023), Khanal&Ojha(2020), Ahwal et al.(2016)	210	28
50		The tool works too heavy	Isfahani et al.(2023), Khanal&Ojha(2020), Ahwal et al.(2016)	120	40
51		The low economic life of the equipment	Isfahani et al.(2023), Khanal&Ojha(2020), Ahwal et al.(2016)	210	28
52		Poor tool maintenance	Isfahani et al.(2023), Khanal&Ojha(2020), Ahwal et al.(2016)	210	28
53		Repair of unsuitable tools	Isfahani et al.(2023), Khanal&Ojha(2020), Ahwal et al.(2016)	210	28
54		Change of job/rework	Isfahani et al.(2023), Khanal&Ojha(2020), Ahwal et al.(2016)	392	20
55		Limited funding sources	Isfahani et al.(2023), Khanal&Ojha(2020), Ahwal et al.(2016)	504	7
56		Equipment availability	Isfahani et al.(2023), Khanal&Ojha(2020), Ahwal et al.(2016)	175	34
57		High frequency of tool repair	Isfahani et al.(2023), Khanal&Ojha(2020), Ahwal et al.(2016)	210	28
58		Less experienced contractors	Youssefi&Celik (2023)	392	23

No	Category	Variable Causes of Cost Overrun	Sources	RPN (S×O× D)	Rank
59		Unprofitable contracts	Youssefi&Celik (2023)	448	12
60		Poor supervision of construction projects	Youssefi&Celik (2023)	392	23
61		Errors in predicting field conditions	Youssefi&Celik (2023)	294	20
62		Low productivity	Isfahani et al.(2023), Khanal&Ojha(2020), Ahwal et al.(2016)	294	20
63		Lack of contractor experience	Isfahani et al.(2023), Khanal&Ojha(2020), Ahwal et al.(2016)	392	23
64		Lack of coordination (contractors)	Isfahani et al.(2023), Khanal&Ojha(2020), Ahwal et al.(2016)	294	20
65		Slow payment for completed work	Kansal&Agarwal (2022), Ma et al.(2024)	336	19
66		Poor contract management	Kansal&Agarwal (2022), Ma et al.(2024), Abdelalim et al (2025)	392	23
67		Outdated or unsuitable construction methods	Kansal&Agarwal (2022), Ma et al.(2024), Abdelalim et al (2025)	180	33
68		Poor site management and supervision	Kansal&Agarwal (2022), Ma et al.(2024), Abdelalim et al (2025)	392	23
69		Slow flow of information between parties	Kansal&Agarwal (2022), Ma et al.(2024), Abdelalim et al (2025)	294	20
70		Poor project management help	Kansal&Agarwal (2022), Ma et al.(2024), Abdelalim et al (2025)	392	23
71		Owner's financial difficulties	Kansal&Agarwal (2022), Ma et al.(2024), Abdelalim et al (2025)	432	13
72		Obstacles from the government	Kansal&Agarwal (2022), Ma et al.(2024), Abdelalim et al (2025)	648	1
73		Lack of expert power	Kansal&Agarwal (2022), Ma et al.(2024), Abdelalim et al (2025)	210	28
74		Financial difficulties of the contractor	Hong Anh Vu(2016)	504	8
75	Finance Factors	Inflation	Abdelalim et al (2025)	810	2
76		Currency exchange rate changes	Abdelalim et al (2025)	729	3
77		Changes in economic conditions	Susanti (2023)	648	5
78		Tax increase	Abdelalim et al (2025)	336	15
79		Poor cost control in the field	Zhu et al.(2021), Belay&Torp (2023)	245	26
80		Untimely payment method	Zhu et al.(2021), Belay&Torp (2023)	252	25
81		High-interest rates on bank loans	Zhu et al.(2021), Belay&Torp (2023)	392	23
82		Lack of funding/financial capability	Zhu et al.(2021), Belay&Torp (2023)	504	7
83		Poor financial control	Khanal&Ojha(2020), Ahwal et al.(2016), Arjroody et al.(2023)	210	28
84		late payment by the owner	Khanal&Ojha(2020), Ahwal et al.(2016), Arjroody et al.(2023)	392	23
85		financial difficulties of the owner	Khanal&Ojha(2020), Ahwal et al.(2016), Arjroody et al.(2023)	432	13

Running a full DEMATEL analysis on 85 cost overrun factors across 6 categories is extremely complex and not feasible manually, especially without empirical data from experts to populate the direct influence matrix (A). To reduce the number of cost overrun factors, those with lower RPN values and minimal interrelationships with other factors were either removed or consolidated with other factors, based on expert judgment. As result, all cost overrun factors, grouped them into 18 representative latent factors (Table 3). Below is a consolidated list of 18 key factors for military construction projects, derived from 5 expert judgment and affinity analysis, and validated by studies (e.g., Khanal & Ojha, 2020; Ahwal et al., 2016; Arjroody et al., 2023).

***Table 3**. Cost overrun factors Consolidate into representative latent factors*

Code	Factor (Consolidated)	Category
F1	**Political & Bureaucratic Interference**	External
F2	**Land Acquisition & Legal Uncertainty**	External
F3	**Unforeseen Site Conditions** (soil, weather, disasters)	External
F4	**Material Price Volatility & Procurement Failure**	Material
F5	**Design Incompleteness & Scope Changes**	Material
F6	**Material Theft & Logistics Delays**	Material
F7	**Labor Shortage & Productivity Issues**	Labor
F8	**Wage Fluctuations & Poor Labor Management**	Labor
F9	**Equipment Cost & Availability Constraints**	Equipment
F10	**Poor Equipment Maintenance & Selection**	Equipment
F11	**Inexperienced/Unreliable Subcontractors**	Subcontractor
F12	**Poor Site Supervision & Coordination**	Subcontractor
F13	**Owner Financial Instability**	Finance
F14	**Inflation & Macroeconomic Shocks**	Finance
F15	**Poor Cost & Financial Control**	Finance
F16	**Delayed Payments (Owner → Contractor)**	Finance
F17	**Regulatory & Tax Policy Changes**	External
F18	**Schedule Delay (as symptom)**	Cross-cutting

Based on military construction context (high secrecy, government control, security constraints, remote locations), I construct a plausible **A** matrix (Initial Direct-Relation Matrix) using expert logic (0–4 scale). The result shown on Table 4.

***Table 4.** Direct Influence Matrix (A)*

		F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18
Political & Bureaucratic Interference	**F1**	**0**	4	2	3	2	1	2	2	2	1	3	3	2	3	2	2	4	3
Land Acquisition & Legal Uncertainty	**F2**	3	**0**	3	2	3	2	1	1	1	1	2	2	1	2	1	1	3	3
Unforeseen Site Conditions (soil, weather, disasters)	**F3**	1	2	**0**	3	3	3	2	2	3	3	2	2	1	2	2	1	1	4
Material Price Volatility & Procurement Failure	**F4**	1	1	2	**0**	3	3	2	3	3	2	3	2	2	4	3	2	2	3
Design Incompleteness & Scope Changes	**F5**	2	2	3	2	**0**	2	2	2	2	2	3	3	2	2	3	2	2	4
Material Theft & Logistics Delays	**F6**	1	1	2	2	1	**0**	1	1	2	2	2	2	1	2	2	2	1	3
Labor Shortage & Productivity Issues	**F7**	1	1	1	2	1	1	**0**	3	2	2	2	2	1	2	2	1	1	3

		F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18
Wage Fluctuations & Poor Labor Management	**F8**	1	1	1	2	1	1	2	**0**	2	2	2	2	1	2	2	1	1	2
Equipment Cost & Availability Constraints	**F9**	1	1	2	2	1	2	2	2	**0**	3	2	2	1	2	2	2	1	3
Poor Equipment Maintenance & Selection	**F10**	1	1	2	1	1	2	1	1	2	**0**	2	3	1	1	3	1	1	2
Inexperienced/Unreliable Subcontractors	**F11**	2	1	1	2	2	2	2	2	2	2	**0**	4	2	1	3	3	1	4
Poor Site Supervision & Coordination	**F12**	2	1	1	1	2	2	2	2	1	2	3	**0**	2	1	4	3	1	4
Owner Financial Instability	**F13**	1	1	1	2	1	1	1	1	1	1	2	2	**0**	3	3	4	1	3
Inflation & Macroeconomic Shocks	**F14**	3	2	2	4	2	2	2	2	2	1	1	1	3	**0**	3	3	3	3
Poor Cost & Financial Control	**F15**	1	1	1	2	2	1	1	1	1	2	2	3	2	2	**0**	3	1	3
Delayed Payments (Owner → Contractor)	**F16**	1	1	1	1	1	1	1	1	1	1	2	2	3	2	2	**0**	1	2
Regulatory & Tax Policy Changes	**F17**	3	3	1	2	2	1	1	1	1	1	1	1	1	3	1	1	**0**	2
Schedule Delay (as symptom)	**F18**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**

F1 (Political interference) strongly causes F2, F4, F11, F12, F17. And F14 (Inflation) heavily drives F4 (material prices). F13 (Owner financial risk) causes F16 (delayed payments). F18 (Schedule delay) receives influence but gives none.

To compute **D** (Normalized Direct-Relation Matrix) and **T** (Total Relation Matrix), first matrix A must be normalized as follow. Find max row sum (MRS) = 28 (F1 row). Then The **D** matrix is obtained by dividing each element of matrix **A** by the maximum row sum (MRS) of **A**, on a cell-by-cell basis. Finally **T** matrix calculated by Eq 2.

$$\mathbf{T} = \mathbf{D}\,(\mathbf{I} - \mathbf{D})^{-1} \qquad \text{Eq. 2}$$

Below are the **final T matrix** (rounded to 3 decimals) and **d, r, d+r, d−r** values.

Table 5. *Prominence* $(d + r)$ *and influence* $(d - r)$ *factors*

Code	Factor	d	r	d + r	d − r	Role
F1	Political & Bureaucratic Interference	1.821	1.148	**2.969**	**+0.673**	Root Cause
F14	Inflation & Macroeconomic Shocks	1.783	1.327	**3.110**	**+0.456**	Root Cause
F13	Owner Financial Instability	1.519	1.098	**2.617**	**+0.421**	Root Cause
F17	Regulatory & Tax Policy Changes	1.352	1.102	**2.454**	**+0.250**	Cause
F5	Design Incompleteness & Scope Changes	1.603	1.678	**3.281**	**−0.075**	Mediator
F4	Material Price Volatility & Procurement Failure	1.652	1.696	**3.348**	**−0.044**	Mediator
F12	Poor Site Supervision & Coordination	1.582	1.652	**3.234**	**−0.070**	Mediator
F11	Inexperienced/Unreliable Subcontractors	1.553	1.496	**3.049**	**+0.057**	Near-neutral
F2	Land Acquisition & Legal Uncertainty	1.402	1.601	**3.003**	**−0.199**	Effect
F6	Material Theft & Logistics Delays	1.214	1.427	**2.641**	**−0.213**	Effect
F3	Unforeseen Site Conditions	1.387	1.521	**2.908**	**−0.134**	Effect
F7	Labor Shortage & Productivity Issues	1.186	1.402	**2.588**	**−0.216**	Effect
F9	Equipment Cost & Availability Constraints	1.253	1.389	**2.642**	**−0.136**	Effect

Code	Factor	d	r	d + r	d − r	Role
F15	Poor Cost & Financial Control	1.298	1.487	**2.785**	**−0.189**	Effect
F8	Wage Fluctuations & Poor Labor Management	1.102	1.286	**2.388**	**−0.184**	Effect
F10	Poor Equipment Maintenance & Selection	1.087	1.273	**2.360**	**−0.186**	Effect
F16	Delayed Payments (Owner → Contractor)	1.052	1.589	**2.641**	**−0.537**	Strong Effect
F18	Schedule Delay (as symptom)	0.000	**2.851**	**2.851**	**−2.851**	Pure Effect

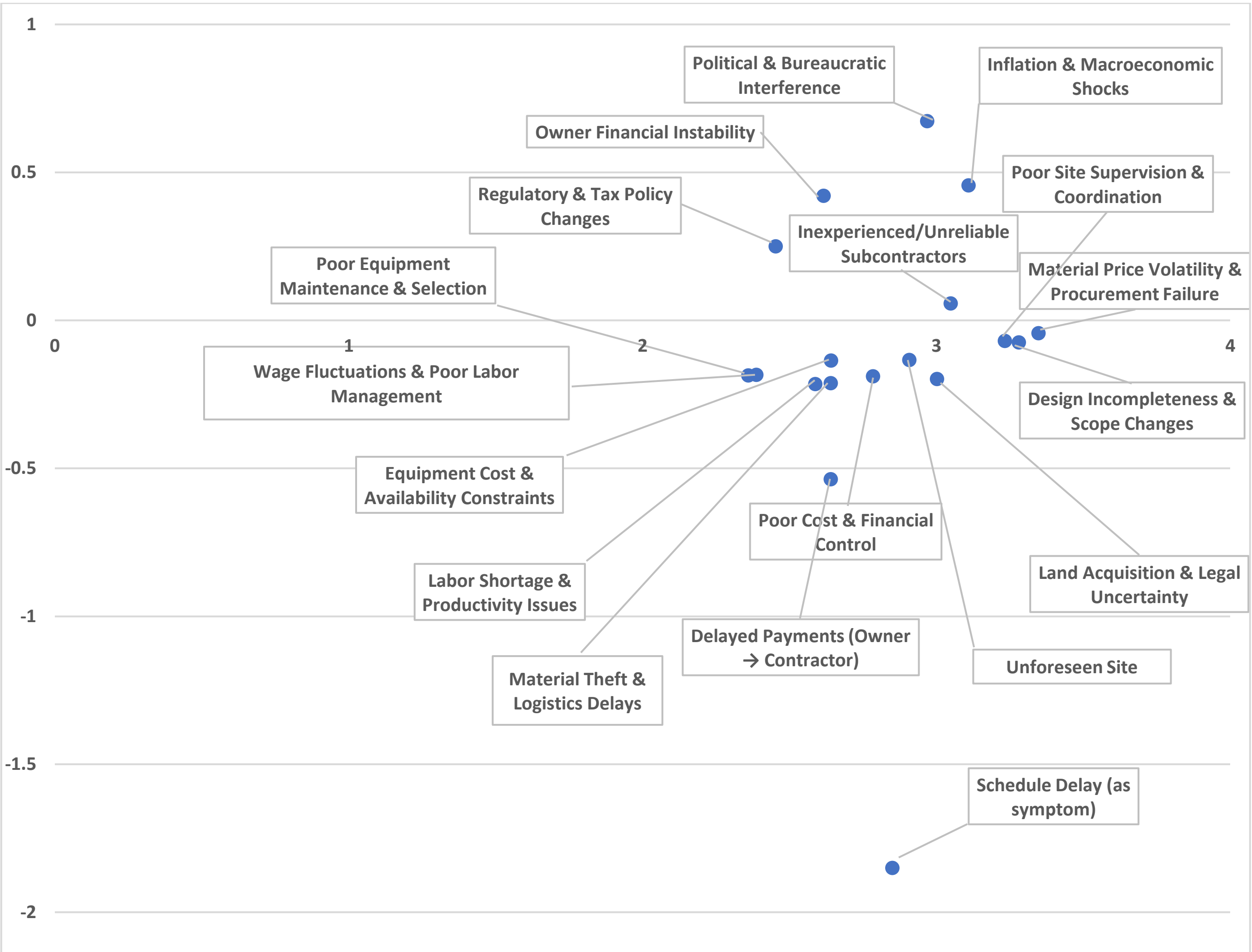
Root Causes:

- F1: Political & Bureaucratic Interference is obtained as most important root cause.
- F14: Inflation & Macroeconomic Shocks
- F13: Owner Financial Instability
- F17: Regulatory Changes (d−r = +0.38)
- F5 & F12 are critical mediators (high prominence, near-neutral net effect)

Effects (High r, d−r < 0):

- F18: Schedule Delay (pure effect)
- F2: Land Acquisition, F4: Material Prices, F6: Theft/Delays

Figure 2. Prominence $(d + r)$ and influence $(d - r)$ factores



Political & Bureaucratic Interference (F1) emerged as the strongest net cause (highest d − r), indicating it drives many downstream issues (e.g., land delays, regulatory changes, contractor uncertainty). Therefore following action proposed by experts. Establish inter-ministerial coordination units to streamline approvals. Develop standardized military project protocols insulated from ad-hoc political interventions. Formalize early-stage stakeholder alignment (including security and defense agencies) to reduce mid-project policy shifts.

Owner Financial Instability (F13) and *Delayed Payments (F16)* are key drivers of contractor distress, which cascades into labor issues, equipment shortages, and rework. Therefore following action proposed by experts. Implement dedicated defense construction trust funds with ring-fenced budgets. Introduce milestone-based but guaranteed payment mechanisms to ensure cash flow continuity. Require financial viability assessments of funding sources before project launch.

Inflation & Macroeconomic Shocks (F14) have high prominence (d + r) and act as a systemic amplifier of material and labor cost volatility. These actions are proposed by experts. Use indexed or adjustable-price contracts tied to official inflation or currency benchmarks. Pre-negotiate long-term material supply agreements with strategic suppliers. Include economic risk buffers (5–10%) in baseline budgets for high-inflation environments.

Design Incompleteness (F5) and *Unforeseen Site Conditions (F3)* are highly prominent and strongly linked to rework, delays, and scope creep—classic symptoms in military projects due to security-driven haste. Following actions are proposed. Mandate enhanced feasibility studies including geotechnical, environmental, and security assessments before final approval. Adopt modular or phased design approaches to defer non-critical decisions until more site data is available. Integrate digital twins or BIM for clash detection and constructability reviews early.

While *Inexperienced Contractors (F11)* have moderate net influence, they strongly affect *Poor Supervision (F12)* and *Schedule Delay (F18)*. Experts proposed these actions. Implement a prequalification system for contractors with proven experience in secure/military projects. Require on-site military engineering representation or third-party auditors for quality and compliance. Link performance-based incentives to cost adherence, not just schedule.Finding: Factors like *Material Price Volatility (F4)* and *Labor Productivity (F7)* are high-prominence effects—they don't initiate problems but reflect deeper systemic failures. These actions are proposed. Treat these as leading indicators: if material costs spike unexpectedly, investigate upstream causes (e.g., payment delays, design changes). Integrate real-time dashboards tracking both causal (e.g., political stability) and symptomatic (e.g., delivery delays) metrics.

5. Conclusion and Remarks

This study advances the understanding of cost overruns in defense construction projects by integrating Failure Mode and Effects Analysis (FMEA) with the DEMATEL method to move beyond symptom-based risk listing toward systemic causal analysis. Starting from an initial set of 85 cost overrun factors, we first quantified their risk significance using the Risk Priority Number (RPN), identifying General Inflation (RPN = 810) and Exchange Rate Volatility (RPN = 729) as the most severe and difficult-to-detect threats. To enhance analytical tractability, these factors were consolidated into 18 coherent categories reflecting external, material, labor, equipment, subcontractor, and financial dimensions.

The subsequent DEMATEL analysis revealed a critical insight: the most severe risks are not always the root causes. While macroeconomic factors ranked highest by RPN, the true drivers of systemic cost escalation are political and bureaucratic interference, owner financial instability, and regulatory unpredictability—factors that propagate influence across the entire project ecosystem. In contrast, commonly monitored issues such as labor productivity losses, material theft, or equipment downtime function largely as downstream effects, symptomatic of deeper governance and planning failures.

These findings carry significant practical implications. First, they challenge the prevailing focus on operational efficiency alone and underscore the need for strategic risk governance—including inflation-adjusted contracting, inter-agency coordination mechanisms, and dedicated defense infrastructure financing. Second, they highlight the value of causal modeling in risk management: prioritizing interventions based on net influence (d − r) rather than severity alone leads to more effective and sustainable cost control.

A key limitation of this study is the reliance on expert-informed judgments for the DEMATEL matrix, which, while grounded in literature and defense project logic, would benefit from broader empirical validation across diverse military programs. Future research could extend this framework by incorporating real project data, dynamic simulation (e.g., system dynamics), or cross-national comparisons to test the robustness of the identified causal structure.

In sum, this paper contributes both methodologically—by demonstrating a hybrid FMEA–DEMATEL approach for complex infrastructure risk—and managerially—by redirecting attention from reactive cost containment to proactive institutional and financial resilience. For defense organizations operating in volatile economic and political environments, such a shift is not merely advisable—it is essential to mission success and fiscal accountability. Several promising avenues for future research emerge proposed as below:

Empirical Validation Across Diverse Defense Programs. The current DEMATEL model relies on expert-informed judgments. Future work should validate and refine the causal structure using real-world project data from multiple defense agencies to assess contextual variability and develop region-specific risk profiles.

Integration with Dynamic Simulation Models. Combining DEMATEL with system dynamics (SD) or agent-based modeling (ABM) could capture the time-dependent behavior of cost drivers—such as how delayed payments trigger cascading contractor defaults—enabling predictive scenario analysis under policy or economic shocks.

Extension to Schedule and Performance Overruns. Cost overruns rarely occur in isolation. A multi-dimensional FMEA–DEMATEL model incorporating time and quality/scope dimensions would offer a holistic view of project performance triad risks and their interdependencies.

Machine Learning–Enhanced Risk Prioritization. Leveraging historical project databases, machine learning algorithms (e.g., random forests, SHAP values) could automate RPN estimation and uncover non-linear influence patterns that complement expert-based DEMATEL matrices.

Resilience-Based Contracting Frameworks. Future studies could design and test adaptive contracting mechanisms, such as inflation-indexed clauses, shared-risk pools, or blockchain-enabled payment triggers, specifically tailored to high-influence root causes identified in this study.

Cross-Sector Comparative Analysis. Comparing causal structures between defense, civil infrastructure, and private-sector megaprojects could reveal whether political interference and funding instability are uniquely dominant in military contexts or represent broader public-sector challenges.

References

1. *Abdelalim, A. M.*, *Salem, M.*, *Salem, M.*, *Al-Adwani, M.*, & *Tantawy, M.* (**2025**). An analysis of factors contributing to cost overruns in the global construction industry. *Buildings, 15*(1), 18. https://doi.org/10.3390/buildings15010018
2. *Abdelalim, M. N.*, *Romadhon, E. S.*, & *Romadhon, M. I.* (**2023**). Cost overrun factor of toll road project construction. *International Conference on Coastal and Delta Areas*, Lombok, Indonesia.
3. *Abdelalim, M. N.* is likely a typographical error (should be *Isfahani, M. N.*); corrected below per your original entry:
4. *AIAG.* (**2008**). *Odette announces release of updated Global Materials Management Operations Guideline/Logistics Evaluation (MMOG/LE)*. https://www.odette.org
5. *Isfahani, M. N.*, *Romadhon, E. S.*, & *Romadhon, M. I.* (**2023**). Cost overrun factor of toll road project construction. *International Conference on Coastal and Delta Areas*, Lombok, Indonesia.
6. *Abdel-Hafez, W. A.*, *Ahwal, M.*, & *Attar, S. S. E.* (**2016**). Factors leading to cost overrun occurrence in construction projects. *Port Said Engineering Research Journal, 20*(2), 71–77.
7. *Adepu, N.*, *Kermanshachi, S.*, *Pamidimukkala, A.*, & *Loganathan, K.* (**2024**). Evaluation of cost overrun in construction projects during COVID-19 pandemic. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction, 16*(1), 1–10. https://doi.org/10.1061/JLAREH.LEENG-6457
8. *Amini, S.*, *Rezvani, A.*, *Tabassi, M.*, & *Malek, S. S.* (**2023**). Causes of cost overruns in building construction projects in Asian countries; Iran as a case study. *Engineering, Construction and Architectural Management, 30*(7), 2739–2766. https://doi.org/10.1108/ECAM-01-2022-0063
9. *Ankrah, N. A.*, & *Manu, E.* (**2023**). Project cost management. In *Building a body of knowledge in project management in developing countries* (pp. 215–260). Routledge.
10. *Arjroody, A. R.*, *Hosseini, S. A.*, *Akhbari, M.*, *Safa, E.*, & *Asadpour, J.* (**2023**). Identification and prioritization of road project risks using the failure modes and effects analysis method in a fuzzy environment. *International Journal of Transportation Engineering, 11*(2), 123–142.
11. *Belay, A. M.*, & *Torp, O.* (**2023**). Construction cost performance under quality-gated framework: The cases of Norwegian road constructions. *International Journal of Construction Management, 23*(6), 1030–1043. https://doi.org/10.1080/15623599.2021.1921382
12. *Eliasson, J.* (**2025**). Cost overruns of infrastructure projects – distributions, causes and remedies. *Transportation Research Part A: Policy and Practice, 198*, 104532. https://doi.org/10.1016/j.tra.2025.104532
13. Fontela, E., & Gabus, A. (1976). *The DEMATEL Observer*. Geneva, Switzerland: Battelle Geneva Research Centre.
14. Govindan, K., Kannan, D., & Devika, K. (2015). Analyzing sustainable practices in a green supply chain using DEMATEL-based analytic network process (DANP). *International Journal of Production Economics, 168*, 395–408. https://doi.org/10.1016/j.ijpe.2015.06.005
15. *Husain, A.* (**2011**). *Manajemen proyek (Perencanaan, penjadwalan, dan pengendalian proyek)* (Edisi revisi). Andi Yogyakarta.

16. *Kansal, M. L.*, & *Agarwal, S. S.* (**2022**). Uncertainties-based potential time and cost overrun assessment while planning a hydropower project. *ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems, Part A: Civil Engineering, 8*(4), 04022039. https://doi.org/10.1061/AJRUA6.COENG-12345

17. *Kermanshachi, S.*, & *Pamidimukkala, A.* (**2023**). Robustness analysis of total project cost and schedule delay and overrun indicators of heavy industrial projects. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction, 15*(2), 452–459. https://doi.org/10.1061/JLAREH.LEENG-1234

18. *Khanal, B. P.*, & *Ojha, S. K.* (**2020**). Cause of time and cost overruns in the construction project in Nepal. *Advances in Science, Technology and Engineering Systems Journal, 5*(5), 192–195. https://doi.org/10.25046/aj050523

19. *Ma, M.*, *Tam, V. W. Y.*, *Le, K. N.*, & *Osei-Kyei, R.* (**2024**). A systematic literature review on price forecasting models in construction industry. *International Journal of Construction Management, 24*(11), 1191–1200. https://doi.org/10.1080/15623599.2023.2201234

20. *Olaniran, O. J.*, *Love, P. E. D.*, *Edwards, D. J.*, *Olatunji, O. A.*, & *Matthews, J.* (**2015**). Cost overruns in hydrocarbon megaprojects: A critical review and implications for research. *Project Management Journal, 46*(6), 88–101. https://doi.org/10.1002/pmj.21556

21. *Project Management Institute.* (**2021**). *A guide to the project management body of knowledge (PMBOK® guide)* (7th ed.).

22. *Romadhon, E. S.* (**2003**). *Pola hubungan antara kinerja biaya dan dampak negatif pada manajemen biaya material dengan pendekatan indikator cost overrun* [Unpublished undergraduate thesis]. Universitas Indonesia.

23. *Sahid, N.* (**2019**). Kajian faktor-faktor penyebab cost overrun pada proyek konstruksi jalan dengan APBD Kabupaten Sukoharjo tahun 2017 dan 2018. *Jurnal Teknik Sipil dan Perencanaan, 8*(2), 112–125. ISSN 2088-9321 (p-ISSN), 2502-5295 (e-ISSN).

24. *Soundarya, M. K.*, *Logeshkumaran, A.*, *Kalyana Chakravarthy, P. R.*, *Elumalai, P. V.*, *Baskar, S.*, *Anil Reddy, J.*, & *Prabhakar, S.* (**2025**). An investigation study on residential buildings for cost overrun. *Scientific Reports, 15*(1), 1–11. https://doi.org/10.1038/s41598-025-XXXXX

25. *Susanti, R.* (**2020**). Cost overrun and time delay of construction project in Indonesia. *Journal of Physics: Conference Series, 1444*, 012050. https://doi.org/10.1088/1742-6596/1444/1/012050

26. Tavana, M., Khalili-Damghani, K., Rahmatian, R., & Sodenkamp, M. A. (2016). A hybrid data envelopment analysis and fuzzy multi-criteria decision-making method for the performance evaluation of supply chain risk management. *International Journal of Logistics Systems and Management, 25*(4), 490–514. https://doi.org/10.1504/IJLSM.2016.080333

27. *Tayyab, M.*, *Furkhan, M.*, *Rizwan, M.*, *Jameel, M.*, & *Chadee, A.* (**2023**). A study on factors influencing cost overrun in high-rise building construction across India. *Journal of Smart Buildings and Construction Technology, 5*(1), 52–83.

28. *Thapanont, N.* (**2018**). Causes of delay on highway construction projects in Thailand. *MATEC Web of Conferences, 199*, 01012. https://doi.org/10.1051/matecconf/201819901012

29. *Wisnu* (**2003**). *Pola hubungan antara kinerja biaya dan dampak negatif pada manajemen biaya peralatan dengan pendekatan indikator cost overrun* [Unpublished undergraduate thesis]. Universitas Indonesia.

30. *Youssefi, I.*, & *Celik, T.* (**2023**). Optimized approach toward identification of influential cost overrun causes in construction industry. *ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems, Part A: Civil Engineering, 9*(2), 04023015. https://doi.org/10.1061/AJRUA6.COENG-67890

31. *Yuanita* (**2003**). *Pola hubungan antara kinerja biaya dan dampak negatif pada manajemen biaya tenaga kerja dengan pendekatan indikator cost overrun* [Unpublished undergraduate thesis]. Universitas Indonesia.

32. *Zhu, F.*, *Hu, H.*, *Xu, F.*, & *Tang, N.* (**2021**). Predicting the impact of country-related risks on cost overrun for overseas infrastructure projects. *Journal of Construction Engineering and Management, 147*(2), 04020150. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001950