Delay Analysis in Urban Infrastructure projects and Mitigation Strategies

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Abstract – *Construction delays are conditions that extend the time required to complete any specific task or entire project beyond the agreed date as per the contract agreement. These delays are legal and financial events that determine the responsible person for delay and the financial liability. This project presents a comprehensive delay analysis to identify and evaluate the primary causes of delay, focusing on typical projects such as multi storied commercial and residential projects, roads and bridges. The research involves a mixed approach like reviewing of established literature, analysis of case studies and collecting survey data from contractors, clients, site engineers, project managers etc. Based on the findings the project develops a set of mitigation techniques. They focus on improving the contractual clarity, implementing advanced project management techniques, improving the coordination among individuals involved in the entire project. The resulting framework provides the project managers, contractors, consultants etc with a practical guide to effectively predict and eliminate or manage the delays and improve the delivery efficiency.*

Key Words: Construction delay1, Mitigation strategies2, Delay analysis3, Questionnaire survey4, Survey data analysis5, Ranking of details6

1. INTRODUCTION

Urban infrastructure development is one of the important factors influencing the modern economic growth. The most formidable challenge of urban infrastructure projects is the failure to adhere to project schedules. Significant delays are predominantly attributed to the relocation of existing underground utility networks such as water pipelines and electrical conduits in congested urban areas and the associated legal and administrative hurdles. The delays in project completion results in significant cost overruns and severely disrupt the daily livelihood and urban mobility.

While conventional project management framework can partially resolve routine construction challenges, they consistently fail to account for the highly dynamic complexities in dense urban areas. So, comprehensive researches in to these urban specific disruptions and formulation of effective solutions are essential for sustainable development.

Anyhow, delays in urban infrastructure projects have consequences like social impact, economic impact and contractual impacts.

2. OBJECTIVES

- Categorize and diagnose the systematic drivers of construction project delays by synthesizing insights from a comprehensive literature review, industry stakeholder interviews and empirical case histories.
- Quantify the impact and relative weight of each disruptive factor using statistical analysis tools to establish a clear hierarchy of risk variables.
- Execute forensic schedule analysis methodologies on a representative urban project to isolate critical path deviations and objectively assign delay responsibilities.
- Develop a strategic mitigation paradigm that embeds modern digital technologies and optimized managerial workflows to provide actionable solutions for curtailing future project overruns.

3. SCOPE

The study analyses execution phase delays across 25-30 construction projects including residential and commercial buildings, roads, bridges and highways among public as well as private projects. The data collection focuses on contractual, managerial, design and regulatory factors with technical construction methods only considered regarding mismanagement or planning issues. Ultimately one project will undergo deep quantitative delay analysis while the remaining projects will inform qualitative insights to propose effective mitigation strategies, such as improved management methods or new software.

4. LITERATURE REVIEW

[1] Rashmi. M. Bijwar and Prof. Dr. A. B. More: In their study on a G+13high rise residential redevelopment project in Andheri, Mumbai, they investigated the core factors driving a 369-day time over run. Through daily onsite data tracking and questionnaire analysis, they concluded that all involved parties shared roughly equal responsibility for the project’s delay. Notably, box plot analysis revealed that the most significant disruptions stemmed from constructor

communication failures and low labour productivity while payments delays, poor contractor coordination, shortage of qualified labour, and government sanctioning processes particularly severe during commencement certificate approvals.

[2] Surbhi Singh: In this research study questionnaire-based survey was conducted in which, data had been collected from various construction sites. The questionnaire designed in such a way that respondents could give their answers based on their opinions and their analysis, for which RII method (relative important Index) was adopted in which the comparison was done between the views of respondents that are contractors, engineers and project manager on the basis of certain parameters. Finally, interpretation of findings was represented in a tabulated form which is easy to understand. This research helps to figure out the critical causes of the construction delay and present data into meaningful form that was in the descending order which depends upon their RII value.

[3] Ahmed El Sayed: In this study, they look into the causes of construction project delays in Bosnia and Herzegovina and assess their importance. This study examines how management software is used during the project planning and execution phases, as well as how precisely inputs are determined.

[4] Jawad A. Alsuliman: The author conducted a survey on delay faced in Saudi Arabia. He has included 50 delay factors and 211 participants were considered and responses were collected. In this top 20 causes were identified and final simplified formula was developed to calculate the effect of each cause of delay onsite. This study mainly considered the part of the government work and was awarded with ranking.

[5] Dixit and Kudari et al. (2021): They addressed delay issues prevalent in the construction industry over several decades. They advocated for enhanced project and technical management, as well as the integration of modern technologies. Their study involved a survey-based assessment, categorizing delay factors into seven groups and comparing them based on impact severity.

[6] Sharmila et al. (2024): Conducted an extensive investigation into the causes of delays in construction projects. Their study highlights key issues in project planning and scheduling that often contribute to time overruns. Using pre structured questionnaire surveys and statistical techniques, the authors analyzed on-site conditions to identify critical delay factors and suggested that proper assessment of these elements is crucial for effective project management.

[7] N. Hamzah, M. A. Khoiry, I. Arshad, N. M Tawil and A.I. Che Ani: In this study it has been discussed about construction delay in Malaysia. They have given delay definition as time overrun or extension of time to complete the project. It has been summarized as delay is a situation which actual construction project is slower than the planned schedule. It involved the category of two types, excusable and non-excusable delay. Further ranks were given to the factors with the help of Relative importance index (RII).

[8] Ibrahim Mahamid, Amund Bruland, and Nabil Dmaidi: In this paper the researcher referred the delay in Road projects. Surveys were collected from professionals such as contractors, clients and consultants. The survey obtained is then analyzed using relative importance index (RII). The top groups affecting the delay in construction are: equipment, design, contractor, material, contract and lastly awarding the tender to the lowest bid price.

5. METHODOLOGY

This study utilizes a structured framework to identify and evaluate construction project delays across Kerala. The research initiated with an extensive literature review to isolate primary causes of delay, which subsequently guided the formulation of a 40-item survey evaluated on a 0-5 rating scale. Primary data was collected from experienced industry professionals handling 30 different construction sites across 5 random districts of Kerala. Following manual commutation and ranking of data, Microsoft excel was used to perform the final analysis and generate comparative visual models including bar charts, percentage-based pie charts for top tier delays and area-based pie charts representing the survey distribution.

6. ANALYSIS OF DELAY

To prioritize delay factors in construction projects, a Severity Index (SI) is calculated based on participant impact ratings. Respondents rate each cause on a scale from 0 (no influence) to 5 (very high influence). The resulting SI scores range from 0 to 100, where a score of 0 indicates complete irrelevance (lowest rank) and 100 signifies maximum impact (highest rank).

$$\text{Severity Index}(\%) = \sum a\left(\frac{n}{N}\right) * \left(\frac{100}{5}\right)$$

Where,
a = constant expressing weighting given to each response, which ranges from 0 for no influence up to 5 for very high
n = frequency of the responses
N = total number of responses

The Severity Index (SI) for each delay factor was computed using Equation (1) from the individual perspectives of contractors and consultants, as well as a combined viewpoint. To determine the overall impact of specific categories, a Group Index (GI) was calculated by averaging the severity indices of all individual causes within that group.

$$\text{Group Severity Index}(\%) = \sum_{i=1}^{n}\left(\frac{Xi}{n}\right)$$

Where,
Xi = severity index of cause i under the group
n = number of causes under the group

To evaluate the level of agreement between contractors and consultants regarding delay factors, the **Spearman Rank Correlation Coefficient (r_s)** was employed. This statistical measure determines the degree of association between two sets of rankings.
The coefficient ranges from **+1**, representing a perfect positive correlation (identical ranking), to **-1**, indicating a perfect inverse relationship. Generally, values approaching **1** signify strong consensus, while values near **0** suggest a lack of correlation between the two parties.

Spearman rank correlation, r_s= 1- [6 * $\sum D^2$ / (n^3- n)]

Where,
r_s= Spearman rank correlation coefficient between two parties

D = difference between ranks assigned to variables for each cause

n = number of pairs of rank

Table -1: Severity Index scale and their impact levels

Range (%)	Impact Level
0	No Influence
0-20	Very Low
20-40	Low
40-60	Moderate
60-80	High
80-100	Very High

Table -2: Delay Factors in Consultant's view

SL NO	DELAY FACTORS
F1	Decision making by Contractor
F2	Issuing of approval documents / obtaining permits from concerned authority on time
F3	Experience of contractor
F4	Faulty work by contractor
F5	Disputes with other parties
F6	Level of equipment operator's skill
F7	Global financial crisis
F8	Financial capability of consultant
F9	Planning and scheduling by contractor before project preceding
F10	Up to date planning and scheduling by contractor for ongoing projects
F11	Site management and supervision by contractor
F12	Strict following of structural designs without any malpractices by the Contractor
F13	Financing by contractor during construction
F14	Productivity level and perfection of work
F15	Satisfaction in selecting the contractor

Table -3: Delay Factors in Contractor's view

SL NO	DELAY FACTORS
F1	Procurement of materials in advance
F2	Delivery of materials
F3	Disturbance to the public activity
F4	Effective communication
F5	Changes in material type and specification during construction
F6	Availability of equipment
F7	Breakdown of equipment
F8	Level of equipment operator's skill
F9	Availability of labours
F10	Absenteeism of labours
F11	Productivity of labours
F12	Labour strike/Union issues
F13	Competence level of key staff from consultant group
F14	Decision making by the consultant
F15	Financing by consultant during construction
F16	Dispute between labours in site
F17	Multiple projects at a time
F18	Perfection of estimation practices
F19	Quality of cost controlling system
F20	Changes in government regulations and law
F21	Effects of social and cultural factors
F22	Unavailability of utilities in site (water, electricity etc)
F23	Weather conditions

F24	Accidents or mistakes during construction
F25	Legal or industrial disputes between various parties

7. SURVEY DATA ANALYSIS

Chart -1: SI of delay factors as per consultant's response

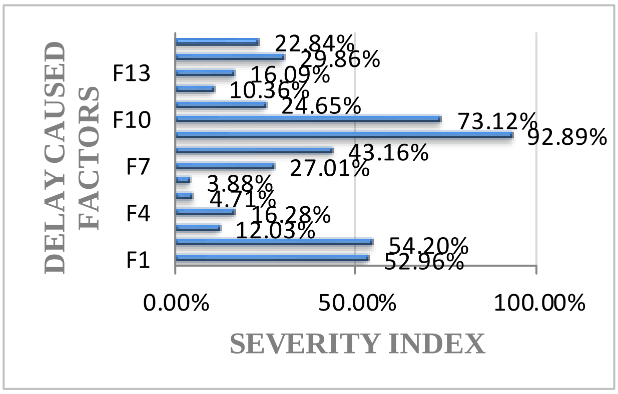
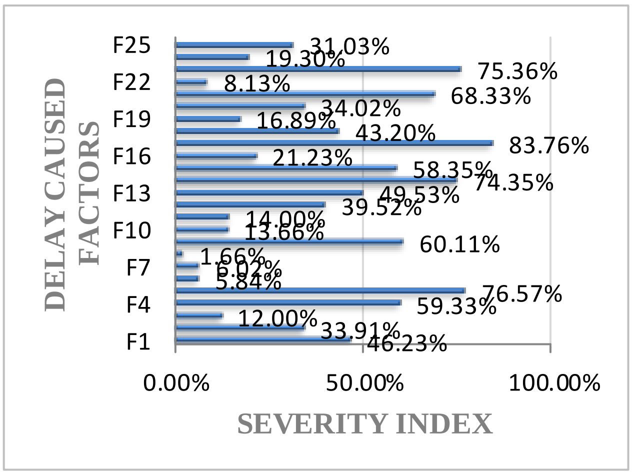


Chart -2: SI of delay factors as per contractor's response



8. RESULTS AND DISCUSSION

Table -4: SI of Delay Factors in Consultant's view &Ranks

SL NO	DELAY FACTORS	SI	RANK
F1	Decision making by Contractor	52.96%	12
F2	Issuing of approval documents / obtaining permits from concerned authority on time	54.20%	13
F3	Experience of contractor	12.03%	4
F4	Faulty work by contractor	16.28%	6
F5	Disputes with other parties	4.71%	2
F6	Level of equipment operator's skill	3.88%	1
F7	Global financial crisis	27.01%	9
F8	Financial capability of consultant	43.16%	11
F9	Planning and scheduling by contractor before project preceding	92.89%	15
F10	Up to date planning and scheduling by contractor for ongoing projects	73.12%	14
F11	Site management and supervision by contractor	24.65%	8
F12	Strict following of structural designs without any malpractices by the Contractor	10.36%	3
F13	Financing by contractor during construction	16.09%	5
F14	Productivity level and perfection of work	29.86%	10
F15	Satisfaction in selecting the contractor	22.84%	7

Table -5: SI of Delay Factors in Contractor's view &Ranks

SL NO	DELAY FACTORS	SI	RANK
F1	Procurement of materials in advance	46.23%	16
F2	Delivery of materials	33.91%	12
F3	Disturbance to the public activity	12%	5
F4	Effective communication	59.33%	19
F5	Changes in material type and specification during construction	76.57%	24
F6	Availability of equipment	5.84%	2
F7	Breakdown of equipment	6.02%	3
F8	Level of equipment operator's skill	1.66%	1
F9	Availability of labours	60.11%	20
F10	Absenteeism of labours	13.66%	6
F11	Productivity of labours	14%	7
F12	Labour strike/Union issues	39.52%	14
F13	Competence level of key staff from consultant group	49.53%	17
F14	Decision making by the consultant	74.35%	22
F15	Financing by consultant during construction	58.35%	18
F16	Dispute between labours in site	21.23%	10
F17	Multiple projects at a time	83.76%	25
F18	Perfection of estimation practices	43.20%	15
F19	Quality of cost controlling system	16.89%	8
F20	Changes in government regulations and law	34.02%	13
F21	Effects of social and cultural factors	68.33%	21

F22	Unavailability of utilities in site (water, electricity etc)	8.13%	4
F23	Weather conditions	75.36%	23
F24	Accidents or mistakes during construction	19.30%	9
F25	Legal or industrial disputes between various parties	31.03%	11

8.1 CALCULATION OF SPEARMAN'S RANK COEFFICIENT

Rank correlation, $r_s = 1-[(6*\sum D^2)/(n^3-n)]$

$= 1-[(6*2)/(6^3-6)]$

$= 0.9$

The positive Spearman's rank correlation coefficient indicates a direct, statistically positive relationship between the perspectives of the contractors and consultants. This alignment suggests that the two stakeholders are mutually interdependent. Consequently, the successful and efficient execution of the project relies on the simultaneous, high-level performance of both parties.

9. CASE STUDY

This case study evaluates the execution dynamics of the civil and electrical rehabilitation works at the Sub-Centre Melangadi in Malappuram, Kerala, a post-disaster public work commissioned to client representative HLL Lifecare Ltd. and contracted to OR Constructions. Contractually bound to a fast track 180-day delivery window starting on 13th March 2021, the integrated civil and electrical works suffered a critical 13-month delay, reaching completion only on 29th October 2022. This delivery slippage triggered severe hardships across all stakeholders: the local community was deprived of primary healthcare services for over a year and exposed to site hazards, the client faced intense public accountability pressure and escalated administrative overheads, and the financially constrained contractor experienced acute cash-flow stagnation compounded by post-pandemic material price escalations. Frontline disruptions began at inception due to severe delays in site clearance, where the failure of local authorities to remove old building demolition waste heavily obstructed initial structural works, an excusable delay for which the contractor formally applied for and was granted a one-month Extension of Time (EOT).

However, while initial site handover impediments, the COVID-19 pandemic, resource shortages and client funding lags undeniably strained the project ecosystem, forensic schedule analysis isolates deficient project planning and scheduling by the contractor as the primary root cause for the remaining extended delay. Operating without a dynamic Critical Path Method (CPM) baseline network, the contractor managed resource allocation reactively rather than proactively, failing to strategically re-sequence overlapping civil and electrical work packages to recover the time lost during the site-clearance phase. Furthermore, the absence of an updated, audited baseline schedule prevented the contractor from providing further data-backed EOT claims to clear administrative bottlenecks. Ultimately, this project serves as an empirical validation that while front-end authority clearings must be stream lined, contractor scheduling maturity and working capital liquidity remain the most critical parameters for safeguarding public infrastructure delivery.

Fig -1: Construction site of Sub-Center, Melangadi, Malappuram

Fig -2: Main slab concreting at Sub-Center, Melangadi, Malappuram

9. FIELD VISITS

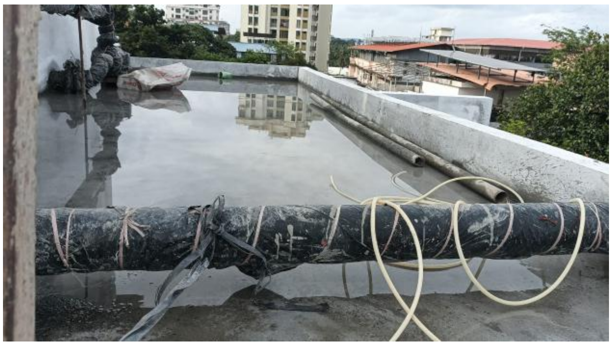


Fig -3: Commercial building for Mr. Justin Alookaran, Thrissur

Fig -4: Renovation works at Family Health Centre, Puzhakkattiri, Malappuram

Fig -5: Commercial building for Mr. Faby Varghese, Cherthala

Fig -6: Construction of Bridge at Munnar, Idukki

Fig -7: Demolition &re-construction of Road at Valakavu to Puthur (BMBC), Thrissur

10. CONCLUSION

This study successfully investigated the primary drivers of schedule variance within urban infrastructure projects across five distinct districts through an extensive field survey. Integrating a comprehensive literature review, the research identified 40 distinct causative delay factors, which were subsequently categorized into six analytical thematic groups. The empirical framework evaluated the severity and relative impact of these factors based on primary data gathered from balanced sample sets of 30 contracting entities and 30 consulting professionals.

The findings underscore that robust project planning and scheduling are paramount to accurate project forecasting and risk mitigation. Incorporating advanced project management software, such as Oracle Primavera, enables project teams to determine individual task costs and establish dynamic resource distribution profiles early in the project lifecycle. This predictive capability strengthens managerial decision-making and project control frameworks. Furthermore, within organizational environments handling multiple concurrent projects, Primavera serves as a critical mechanism to prevent resource over-allocation through systematic resource optimization. By utilizing built-in diagnostics, such as the resource usage spreadsheet located at the baseline interface of the software window, project managers can identify over-allocation early and apply resource leveling techniques. Ultimately, this research validates that transitioning from traditional methods to real-time, software-driven scheduling is a vital step toward reducing delays and optimizing resource efficiency in complex infrastructure networks.

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