CHAPTER 11

Assessment of Delays in Construction of Water Infrastructure Projects and their Cost Escalations

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ABSTRACT

Infrastructural projects have a very important role to play on economic development, yet they are still faced by delays and cost overrun, which is particularly true in the developing economies like India. This empirical study paper will discuss the primary causes of delays, the current practices on the ways to reduce risks, and the implementation of innovative technologies. Our methodology was mixed because we balanced both the in-depth literature review and the responses of 36 industry participants in the form of surveys. Findings show that administrative delays (government approvals, land acquisition) are the most deplorable determinants of delay with 47.2 percent of the projects experiencing 10-30 percent schedule overruns. The moderate effectiveness is seen with the Critical Path Method (CPM) and with Risk Assessment Matrices (52.8% rating) and there appear to be high adoption barriers to BIM (41.7%), AI/ML (8.3%), and blockchain (2.8%). The approval delays have been found to be the most important factor by the Relative Importance Index (RII) analysis of the approval delays (RII=0.81). We propose a risk management model, which is dependent on technology integration, which bridges the gap between reactive and proactive project governance and the data-driven project governance.

1.0 Aim

Experiment with more effective methods to organize construction, including team-oriented methods (think IPD), in which the parties share an equal deal of risks. IPD strains collaboration on deals, equalizes risks but specifically ties salary to performance - aiding easier workflows and lessening disputes so individuals collaborate.

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Local solutions to sewer repairs produced such clever tactics as rapid field inspections as well as group contracts which fit the needs of the locals. The same applies to water sharing in Mexico which involves farm and city use as the tracking tool to gauge the nature requirements. We can see through rural China how change of leadership is creating a stronger long-range set-up. Out in Arizona, using real-time info streams, urban planners make tweaks - all cases indicate that there is no way to fit solutions elsewhere.

1.1 Research objectives

- *Investigate delay factors:* Labelling: Classify technical, environmental, financial, regulatory and managerial factors that lead to project delays in water distribution infrastructure projects.
- *Dissect project management strategies of delay:* Measure the impact of project management techniques (scheduling, allocation of resources, coordination of stakeholders) on the probability and degree of delays.
- *Quantify cost increases:* How does project delays affect the total costs of the project, both direct (labor, materials) and indirect costs (penalties, opportunity costs)
- *Explore long-term impacts:* Research on whether construction or the delay in commissioning of water distribution systems may impact the long-term functionality and sustainability of the water infrastructure.
- *Proposing strategies:* To offer a solution of strategies and recommendations (e.g., Procurement techniques, Contractor choosing approach, Risk management system that might aid in lessening of delays and the transaction cost of such delays in water distribution project.

2.0 Introduction

The difference between a thriving society and places where business cannot survive is clean, reliable drinking water - which not only safeguards human health but also increases employment opportunities locally but also keeps daily operations going. The supply networks come to the city as well as small communities and ensure that everything runs smoothly without hiccups and risks. They mostly apply elevated reservoirs known as ESRs with tough HDPE pipes - both can endure the test of time and cut costs. This makes the push by the lines since these tanks are elevated. HDPE pipes bend easily without breaking and easily deal with uneven ground. Nevertheless, even a well-performing gear still chugs at a crawl; certain projects sometimes - this push works against other projects at the cost of holding clean water until needed in time and place by the folks. When systems fail to perform efficiently in villages, installation of water tanks and plastic pipes requires an eternity, which makes clean

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water a nightmare, and also exposes people to diseases. Poor roads with the scarcity of supplies push things even to the limit in terms of the financial pressure. The congestion seen in urban cities requires teams to navigate between and through a wide range of actors and address levels of regulations, keeping things at a standstill. This stalemate translates to an increase in wait time to free flowing services, increase in bills, services slacking, and shutdowns becoming the order of the day.

The work of late clean water was burning cash. Failure to meet deadlines result in increased costs - crews will remain longer, materials will become more expensive, fines will accumulate as deadlines are not met. In the meantime, the locals are hurt because jobs have stagnated, town economies are shaky, diseases are transmitted through dirty taps. In order to add to that, inflation is creeping upwards, supply cost is up and down; and as the environmental or safety regulation changes the totals are even higher.

This project analyses delays in water systems that have high tanks and plastic pipes both rural and urban. Inequality in planning does not only slow down the progress itself but also drives the costs upwards, making rollout difficult. Instead of identifying individual factors, the study examines the manner in which fragmented teams end up putting pressure on schedules across the country. Failing to deliver on time or having insufficiently trained workers will cause a breakdown within a short period when there is no viable solution. The first step to fill these holes is to change the way crews establish the work immediately - reconfiguring approaches to their needs of the specific location. Alternatively, rather than wait, communicating early about the building work, leaders, and residents prevent larger snags in future. The timely arrival of supplies is also maintained by altering the way supplies are ordered hence the workers do not just stand around. Holdups are also reduced by being more considerate when establishing projects - despite the lack of cash. In summary: clean water is delivered to the community at a lower rate and is faster.

3.0 Literature Review

3.1 Connection between literature review and the Agra district water supply scheme case study

The Agra District Rural Water Supply Scheme under the Jal Jeevan Mission is indicative of most of the systemic issues raised in the body of water infrastructure literature the world over and in the region. Instead of a one-time project failure, the case study illustrates how repeating delay causes, governance lexical as well as planning flaws or coordination failures long since documented in previous studies are realised in an actual Indian rural set-up. The literature reviewed jointly offers the theoretical background, benchmarks of comparison and the analytical tools in respect to which the Agra case can be interpreted, justified, and comprehended.

The pivotal point of the literature is the vast literature on the causes and effects of delays in drinking water development projects, specifically the case of Sri Lanka as reported by Perera and Halwatura. Their list of major drivers of delay includes slow client decision making, low stakeholder co-ordination, weak planning, financial stress on contractor and late payments; this list can be almost directly traced in the Agra scheme. The administrative inefficiencies, slow disbursement of fund, slow approval, and poor inter-department convergence witnessed in Agra is similar to the owner- and consultant-related factors, which registered the highest rate of agreement (79-82%) in the Sri Lankan and global data. This correspondence justifies the Agra case as being empirically consistent with the delay theory but not an exception.

The proposed criteria of strategic characterization of water infrastructure management by Garvin (2003) help in understanding the nature in which these delays are followed up by systemic under performance. According to Garvin literature, water projects are mostly unsuccessful when the institutional, financial and governance capabilities are not linked to the delivery of technical assets. This lack of connectedness can be observed in Agra in the distance that exists between the DPR preparation, procurement decisions, field execution, and community engagement. Physical specifications were done on the physical properties, like ESRs, HDPE pipelines and solar pumps but due to the lack of integration of institutional preparedness and operational planning, redesigns, re-working, and schedule slippage were frequent. Therefore, the framework by Garvin explains the macro level of poor performance of technically good projects when the system-level alignment is poor.

The perspectives of the literature on Integrated Project Delivery (IPD) and Gokhale (2012) in particular can be used to understand why the case of Agra did not overcome the effects of these challenges by employing traditional models of the delivery. The literature highlights the designs-bid-build structures fail in uncertain circumstances, the bifurcated responsibility, and late entry of the contractors which are the conditions which have manifested itself dominantly in rural water undertaking. In Agra, there were mobilization of contractors once the finalization and design errors were identified in execution and the risk was asymmetrically distributed. The study is directly informed by the literature on IPD that collaborative contracting and early stakeholder engagement and common risk-reward mechanisms had the potential to reduce rework, enhance coordination, and eliminate adversarial delays.

This point is also supported by the adaptive and agile project management literature (Lanier and Sukop, 2016), which emphasizes that interdisciplinary infrastructure projects involving the integration of the all the mentioned aspects of civil, mechanical, electrical, and

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renewable energy require a flexible governance approach and iterative decision-making. The challenges of the Agra scheme in the incorporation of solar pumping systems into civil infrastructure and electrical systems are good examples of the impacts of fixed silo-based management thinking. The literature therefore justifies the inability of the traditional linear planning to react well to emerging site realities, monsoon shocks as well as issues on technology integration.

The insights on the operational level presented in the literature on rural water supply management (Li, 2019; Li, 2020), are directly related to the post-construction risks of Agra, as well as the community-related issues that Agra faces. These articles draw attention to the fact that sustainability is based on community engagement, financial sustainability, and institutional ownership. The lack of empowerment of the Village Water and Sanitation Committees (VWSC) in Agra and the reduced level of community involvement and poor communication resulted in resistance, land issues, and tardiness in household connectivity. The fact is supported in literature, that the delays are not only technical or contractual but have social or governance elements foundations in rural water systems.

Financially and risk-wise, the literature on the PPP failure and the risk driver (Tariq and Zhang, 2020) enhances the concept of contractor distress that is realized in Agra. Despite the fact that the project was not a full PPP, there were several PPP-like risks, including the delay in receiving payments, exposure to inflation weak allocation of risk, and the rigidity in the regulatory board. Literature describes the causes of the loss of margins, cash-flow pressure, and the work being thrown away in certain occurrences which gave back to the project delay and cost increase.

It has been indicated in the asset management and capital prioritization literature (Thornton et al., 2012) that explains the erosion of identifiable costs and benefits over time in Agra. Delays made benefits realization, and cost life-cycles higher thus making the investment economically ineffective. Lack of preventive planning of assets and prioritization based on the condition in the implementation process is in line with caution in the literature that lapses in asset governance would increase cost overruns and reduce sustainability in executions.

Lastly, the methods of water scarcity modelling (Hernandez-Cruz et al., 2023) and network partitioning algorithms (Tian et al., 2022) are advanced study techniques that made their mark on the overall methodological input of the study. Although these methods were not used in Agra, their omission is a reason why the planners were unable to resolve many planning issues, including failures to optimize pipeline routes, pressure failures, and energy losses. These works justify the research hypothesis that the combination of modelling tools, GIS, and data-driven decision-making in the DPR stage may help to cut down the delays and operational inefficiencies in the downstream significantly.

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4.0 Research Methodology

4.1 Root Cause Analysis (RCA) – Agra rural water supply scheme

Problem Statement: The Agra Rural Water Supply Scheme is a mass infrastructure project that was undertaken under the Jal Jeevan Mission (JJM) through the State Water and sanitation mission of the Government of Uttar Pradesh and is designed to be used to roll out functional supply of household tap connections to the rural population. The project will entail the design, constructions, commissioning, and long-term running and upkeep of surface water-based supply structure (Elevated Service Reservoirs (ESRs), HDPE pipeline networks, pumping system and other related facilities).

According to the Letter of Award (LOA), the project has been awarded to M/s Megha Engineering and Infrastructure Ltd. and has the total value of 1,085.66 Crores and includes:

Capital Expenditure (Capex): 964.36 Crores.

Operation and Maintenance (10 years): 121.29 Crores.

A premium was quoted on the nominal contract being (-0.45%), which may be referred to as a competitive bid environment and quality financial margins. The project schedule, as stipulated in the contract terms, was designed to be on a normal execution time of about 24 months, and a 10-year operation and maintenance was thereafter.

Though the project was highly planned, its scope and financial allocation are high, the project has suffered major setbacks in the implementation process that has seen the actual implementation of the project extend to around 30 or 34 months, which is almost 30 or 40 months above the planned date. These delays have led to increased costs, ineffective use of resources and slowing of socio-economic benefits especially in rural communities that also need better access to water supply.

5.0 RCA Analysis

The Root Cause Analysis follows a structured breakdown across five key dimensions: The Root Cause Analysis is based on a systematic dissection in 5 important dimensions:

Administrative Inefficiencies: Money is received with a lag, wait is protracted, and documents pile up - one slackening a thing in her hurry. Clearances are frozen unexpectedly longer when Jal Nigam trails behind local crews or neighbouring units. That stalling strangles the workers; purchase can be made at an even greater distance - so no movement along, but stumbling.

Technical Planning Gaps: The DPRs were typically not relying on trusted technology - e.g. GIS maps - so there was a high percentage of design failures or vacant

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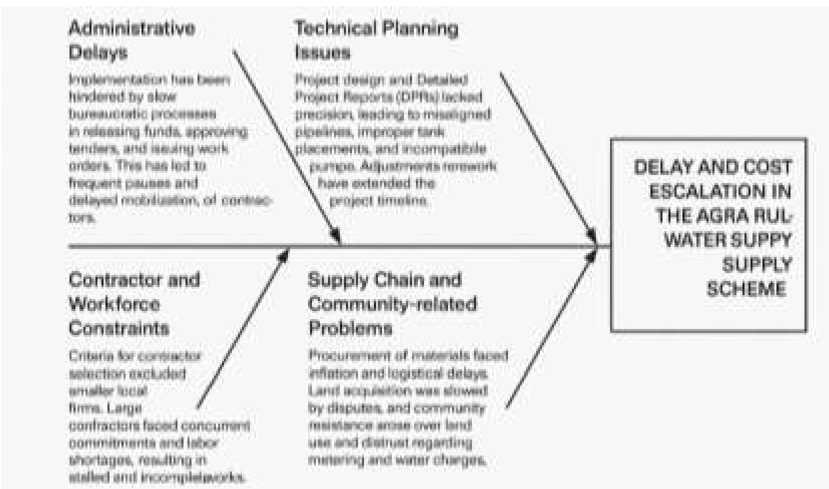
designs. Immediately after the start of the construction, the problem of layout appeared almost immediately, and teams had to go back and rectify large areas. To top that, plumbing, wiring, and structure components almost never fit very well and, therefore, it took funky time to connect solar equipment with the water systems.

Contractor and workforce constraints: The crew hardly increased due to the regulations that left the locals at the backburner, leaving bigger firms with the first option of crowded working sites. Such discrepancy resulted in wobbly staffing every now and then, spotty performance here and there, whereas certain tasks were just dropped when funds or supplies were low.

Supply chain disruptions: Shipments were slow due to floods, and prices of materials were increasing, which put a strain on the supply of pipes and fittings. Deliveries reduced - reaching a single point, with no additional storage nearby. Rises in solar equipment prices had also imposed an increase on the overall costs.

Community and social factor: False reports raised headaches in a number of areas, and fights arising over the use of the land with authorities intervening occasionally. The locals were sidelined - VWSCs lacked a face of authority or support and thus the locals lacked trust and thus managing to resolve local conflicts were slow.



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6.0 RCA Diagram

The RCA method of the Agra rural water project bypasses the typical split-path design - rather, the design takes the right path one step at a time through all the major causes, demonstrating how each of them contributes to longer wait and increased costs.

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The biggest issue? The rural water push in Agra has regressed far behind - although the cost increases persist. There are six main drivers of this mess, each of them different, but interconnected, and silently amassing stress on every side.

Things became hard to lead because paperwork was obstinate, groups hardly kept in touch with each other - coupled with a haphazard money handling and confusing expenditure queries. All this housekeeping stood in the way of anything, delayed the teambuilding, pushed start dates as well.

There were not as many experienced people to hire: most were kept busy in other areas. There were locations where there was no local work force with appropriate skills and this slackened the pace. Top to that, rural water teams were not making much of a stir; it could be that their introduction earlier in the process could have prevented the growth of minor problems. The problem of shipping as well as the slow-order contributed significantly. Pipes, valves, or building materials are hit by delays - frequent glitches exacerbated by the increase of cost and fluctuating price, especially of solar equipment or associated items. Orders were done in one center and local transportation was slow meaning that daily items were barely in flow leading at times to a stall in the work process.

This went awry at an early stage due to the failure of the plans being done in a proper manner. At the midway point, the designs needed to change - the initial designs were missing major details. In their absence, such as GIS, the pipes were installed at the wrong locations, and the tanks descended into slopes of the land. Quality inspections were inconsistent or even reduced to non-existence hence errors accumulated and costly repairs were made.

Problematic equipment made it slower with the introduction of solar pumps. The chosen kit was unable to accommodate village wells and therefore issues cropped up. To make things worse, there was inadequate supply of skilled workers thus dragging installations.

Finally, and not the least, the place where things occurred caused its share of downfall. This is the time that each rainy season struck - work came to a standstill, trails became messy, equipment started to malfunction. Added to that, locals became edgy; people complained of lost space, bosses changed office at will, which disrupted schedules. In the absence of obvious means to disseminate information, rumours were going viral killing the morale in certain regions permanently.

6.1 Engagement and communications to the stakeholder

The Jal Jeevan Mission in Agra Rural Water Supply project, the involvement of the people coupled with sharing of information were the factors that influenced the rate of progress, the buy-in of locals and the actual success of the project. Since the purpose was to provide tap water to the people in various villages, the organizational element would have to

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encompass all the aspects, not only the officials that could make decisions but also the locals that had to address the consequences.

Nevertheless, the manner in which things were developing indicated that there were continuous problems with which groups collaborated or communicated news. In addition to this, government organizations - such as Jal Nigam or public health departments - were to be established to lay down plans, disburse cash but accelerate greenlighting procedures. Even though its intentions were strong, giant lags on major data appeared. Each team worked independently without having effective means to keep pace in real-time. This time lag caused projects to be delayed, communication was not fast enough in making corrections in the blueprints, and problems such as headaches in technical details, mostly related to solar-powered units and links to energy networks. The wiring group, construction group or machinery crews would often go in different directions, skip check-ins, duplicate efforts, and sometimes do a re-do that would have been avoided had it been better positioned.

Nobody had any idea of what was happening down on site. The lack of enough hands combined with many crews involved with deadlines and too many crew meant that delays were greatly experienced whenever priorities changed- especially in cases where no information was received fast. When things were changed when it came to requirements or terms of purchase, the news leaked slowly - or not at all - and derailed, scheduling, both in the case of labor and supplies. Groups under unsteady leadership turned out to assume rather than know thus causing errors to accumulate and go far off course.

There was less entry of village crews such as Water and Sanitation Teams, creating confusion. These organizations ought to have linked locals to constructors. Theoretically, they would be checking on work, volunteering, or making an appeal. But there were a lot who doing barely worked, were intermittently directionless or never received proper training. There was no actual participation, and problems accumulated, creating tension and suspicion. This was evident when there were confrontations over land to be used in pump stations and this was worsened by pipelines going through the private land. They found it difficult to get the permission of people living close to them when there were no local go-betweens who had anything to say on how to iron out tensions.

The introduction appeared unjust and incoherent to most of the residents. As much as there was hoped to gain, the majority were not aware of gain, construction noise, traffic jam, or impending maintenance chores. Where the facts were unavailable through the official channels, rumours in their place were having a handicap - the result was an angry reaction in some neighbourhoods, on their part. No initial discussions, informal visits, or even simple information sessions made the initiative be seen by people as support and more as a pressure that has been dropped on their door.

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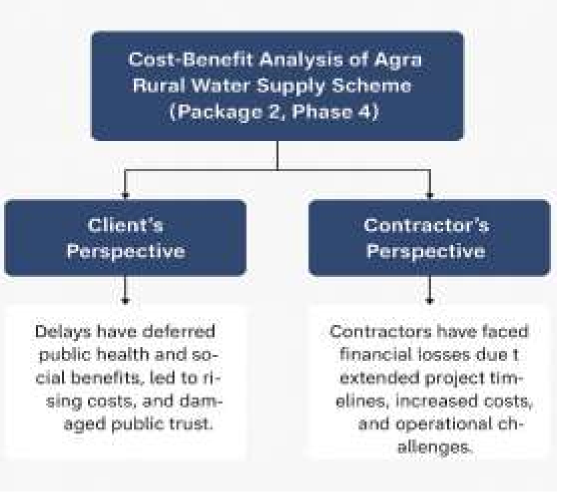
Nonetheless, some places succeeded to get progress by communal discussions. When the elders scheduled gatherings, and dragged country reps on board immediately, the turn of events was more noticeable. It demonstrates that when locals facilitate the discussion, things normally turn out to be much better.

Some minor adjustments assist in solving these issues. Begin with the establishment of small units in every region to ensure that the offices remain local. Choose good talkers who visit occasionally and not just one time only. Train community water teams including real tools and helpful expertise. Also demand constructors to meet citizens and technical personnel frequently under firm contracts - all combine the efforts of everyone.

This illustration shows that crafting in rural India requires individuals initially. It will not be served by machines or plans, but only by actual chat. Communicating should not be put on afterthought, but should be incorporated in the planning, construction, launching, and even fixing things in the future. Lose that constant link Even ingenious solutions may fail because the locals may fail to support them or may feel excluded.

7.0 Cost Benefit Analysis



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7.1 Time chainage analysis

The Agra Rural Water Supply Scheme as a project under Jal Jeevan Mission had a deadline of two years in the beginning. The following schedule covered every activity - plan writing to installation of operational taps in the houses in the chosen villages. However, the real progress was below what was expected. The setbacks overlapped and the completion was delayed to approximately 32 or even 34 months. The long duration increased the costs besides postponing benefits to inhabitants.

DPRs, site visits or purchase setups were expected to begin within the project in the first half of the year. However, instead of rushing, it struck with loads of paperwork delays. The lack of approvals, the absence of such tools as GIS maps, and the discussions within the teams about the details, extended the timeframes to absolutely beyond the schedule. DPR services alone required almost eight weeks additional - as the path of the pipes or pump power was never established, without being moved at the outset.

The next was the stage of hiring and setup, which was supposed to be completed within three months but it again went awry. Tough eligibility provided served as a reduction of the number of businesses that could participate and a number of bids were cancelled or relocated under the cost restrictions. Due to this fact, the three months of hauling the teams and equipment to the site was extended by eight weeks. During this time, the contractors were having difficulties with governing and dismissing personnel and equipment because they are both bound in parallel civil undertakings by the government.

The second work, the main trench, which was to be started in the 7th month up to the 14th month, was also started late. By the time the teams moved in, it had already soaked in down and excavation at multiple spots was made more difficult. Land demarcation fights, unresolved documentation or clearance-come-clearance ensued, and slowed the progress. This was the only segment that increased by almost half a year because one problem had built over another.

The second huge undertaking - the installation of pump stations, installation of elevated water storage facilities, as well as the interconnection of pumps that are solar-powered, took close to three months behind schedule. The supply of supplies, particularly machine parts and electrical cables, have been delayed through reasonably unreliable deliveries and inconsistent prices of solar equipment. Most of the installations were later to be re-done due to a lack of compatibility in requirements; and few knew how to use the new systems. The duration of testing and the mode of commencement should not exceed three months but dragged beyond expected length - extra work came in, leaks were being taken care of, pressure on the network on one or other side was being tested. Once more the time lag between construction and cablers corrupt exercises, pushing the timeline forward by forty weeks. Finally, water line connections to houses - which should be completed by month 24 - lagged on until month 30 or 32. Strict schedules were leading to delays; opposition in some villages further increased the time lag. VWSCs could not easily speak to the households without having real power and therefore connection sign-offs required more time.

A schedule meant to be completed in two years was only completed nearly ten months behind schedule. Due to the time-wasting nature of it, costs skyrocketed - man hours

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invested, equipment utilized and bosses who hung about all long after time constraints. Concurrently, real gains to communities were postponed as well. The locals continued to use unsafe sources of water; what is worse, the gradual evolution made them more sceptical of the activities of governments.

8.0 Data Analysis

By using the secondary data, PART 1 – Sri Lankan Study (Perera & Halwatura 2012)
Sample: 54 valid responses (Contractors = 21; Clients = 15; Consultants = 18)
Scale: 1–4 Likert (1 = Not Significant, 4 = Highly Significant)
Computation: Relative Importance Index × 100 → % agreement
Delay Causes and Respondent Agreement (%) Sri Lanka (Perera and Halwatura, 2012)

The table enlists project-related delay causes - so-called Category A - and levels of agreement. There were 6 major issues raised that were supported by 70% to 78% of the respondents, indicating that most of them consider these issues. Unrealistic time schedules were the top at 78 with frequent increase in scope coming second with 76. Strong consensus was noted in the passing of information between teams; and confusion in the ownership of risks. The problem of land acquisition resulted in stalling of many, but the contribution of the officials did not lag far behind. On balance, 74 percent of them admitted to these challenges with internal management gaps having been identified as a fundamental problem.

Div.	Delay Cause (39 Total)	% Agreement (All Respondents)
A. Project-Related Causes		
A1	Frequent changes in project scope	76%
A2	Inadequate project duration / unrealistic schedule	78%
A3	Poor coordination between stakeholders	74%
A4	Improper risk allocation / assessment	70%
A5	Delay in site possession / land acquisition	73%
A6	Delay due to environmental clearance or local authority approvals	72%
Average (A)		**≈ 74%**

Source: Created by authors

8.1 Causes owner / consultant causes (category B)

The table shows the cause of delays with owners and consultants - a majority concurred with 74 percent to 85 percent. Selecting things that were too slow or a delay in approvals was 85; however, late payment came at 82. Beyond that, the lack of enough workers was a problem - as was lingering on to collect drawings to be signed off or clients changing

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their mind on a whim. Dubiously, around 79% of them indicated that these factors have a significant impact on project speed.

Div.	Delay Cause (39 Total)	% Agreement (All Respondents)
B. Owner / Consultant-Related Causes		
B1	Delay in progress payments by client	82%
B2	Slow decision-making and approvals	85%
B3	Delay in approving shop drawings / documents	77%
B4	Lack of competent staff in client/consultant organization	78%
B5	Unrealistic expectations or frequent client interference	75%
B6	Lack of communication between consultant and contractor	74%
Average (B)		**≈ 79%**

Source: Created by authors

8.2 Contractor-Related Causes (Category C)

The following table enumerates issues of contractor associated with delays in terms of the points of agreement, the highest being 88-77%. Inadequate on-site surveillance and inadequate oversight were 88 and 84 percent respectively as compared to unstable planning and disorganized scheduling which were the most important issues. The problems of finances followed closely as well as lack of skills; sporadic inspections coupled with reworks as a result of poor workmanship became a point of wide interest. With an average of 82 percent support, it is clear that performance by the contractors slows down the projects at a high rate.

Div.	Delay Cause (39 Total)	% Agreement (All Respondents)
C. Contractor-Related Causes		
C1	Poor site management and supervision	88%
C2	Inadequate planning and scheduling	84%
C3	Financial difficulties of contractor	79%
C4	Inadequate experience of contractor	81%
C5	Poor supervision and lack of quality control	77%
C6	Rework due to poor workmanship	78%
Average (C)		**≈ 82%**

Source: Created by authors

8.3 Design-Related Causes (Category D)

The table includes the reasons behind design delays, and the results are acceptance of around 72 to 80% or the majority of people are okay with it. Lacking design specifics made

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80 percent; wrong or incomparable designs are at 78 percent - highest ranked problems identified. Continuous design modifications in addition to the lack of communication between office designers and workers on the sites contribute to delays. About 76 percent say so in general, noting that the quality of the designs - along with the manner in which they are shared in the first place is a significant contributor to failing to meet deadlines.

D. Design-Related Causes		
D1	Incomplete design details	80%
D2	Frequent design changes	76%
D3	Design errors / mismatched drawings	78%
D4	Poor coordination between design and site	74%
D5	Poor communication between consultant teams	72%
Average (D)		**≈ 76%**

Source: Created by authors

8.4 Material-Related Causes (Category E)

This table describes material-related delays - they were unanimous (ranged between 74% and 81). The top of the list was taken by 81% of the blame, which was attributed to late deliveries, followed faithfully by the quality of the item and incomplete orders. The bottlenecks also emerged as approval factors. Overall, about three out of four concurred completely with each other and indicated that more intelligent buying and managerial practices could reduce the number of hiccups.

E. Material-Related Causes		
E1	Late delivery of materials	81%
E2	Poor quality materials	78%
E3	Unavailability of materials	76%
E4	Delay in material approval process	74%
Average (E)		**≈ 77%**

Source: Created by authors

8.5 Equipment & Labour–Related Causes (Category F)

What comes out in the table is the cause of delays with equipment and labor - consensus is at between 76-80 which is an indication that there is just one opinion. At the head is equipment breakdowns with an 80 percent shortage of skilled workers with only 79 percent a second place. Missing or forgotten tools slow down the growth - but poor productivity and frequent absences apply further pressure. Approximately 78 percent of them feel that they can have reduced idle time with better maintenance as well as smarter team planning.

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F. Equipment & Labour-Related Causes		
F1	Equipment breakdowns	80%
F2	Shortage of equipment	78%
F3	Poor maintenance of equipment	76%
F4	Shortage of skilled labour	79%
F5	Labour productivity issues / absenteeism	77%
Average (F)		**≈ 78%**

Source: Created by authors

8.6 External Factors (Category G)

This table brings out the external causes of delays with the approval score of 70 to 75. The rainy days made it to the top leading with 75 percent and edging out other outward influences. Difficulty in acquisition of land came next right behind and was bound up in court cases. Policy changes also bring things up. Supplies Price increases went up as well. Delays were also due to slow utility work - or lack of coordination with local agencies. Approximately, 72 percent responded in the affirmative, as these problems are not entirely avoidable, but tend to derail timelines.

G. External Factors		
G1	Adverse weather conditions	75%
G2	Political interference / policy changes	71%
G3	Fluctuation in material prices	70%
G4	Delay in utility shifting or local authority coordination	72%
G5	Land acquisition / legal disputes	73%
Average (G)		**≈ 72%**

Source: Created by authors

PART 2 – Cross-Study Global Synthesis (Assaf 2006; Sambasivan 2007; Chan 1997; Aibinu 2002)

Samples Combined: ≈ 330 respondents across 4 countries

Scale Conversion: RII × 100 = % agreement

Aspect	**Assaf & Al-Hejji (2006)**	**Sambasivan & Soon (2007)**	**Chan & Kumaraswamy (1997)**	**Aibinu & Jagboro (2002)**
Sample Size	72	94	84	82
Respondents	Owners, Consultants, Contractors	Clients, Consultants, Contractors	Clients, Consultants, Contractors	Contractors, Consultants
Scale	5-pt (Frequency & Severity)	4-pt (Likert importance)	5-pt (Importance)	5-pt (Importance)

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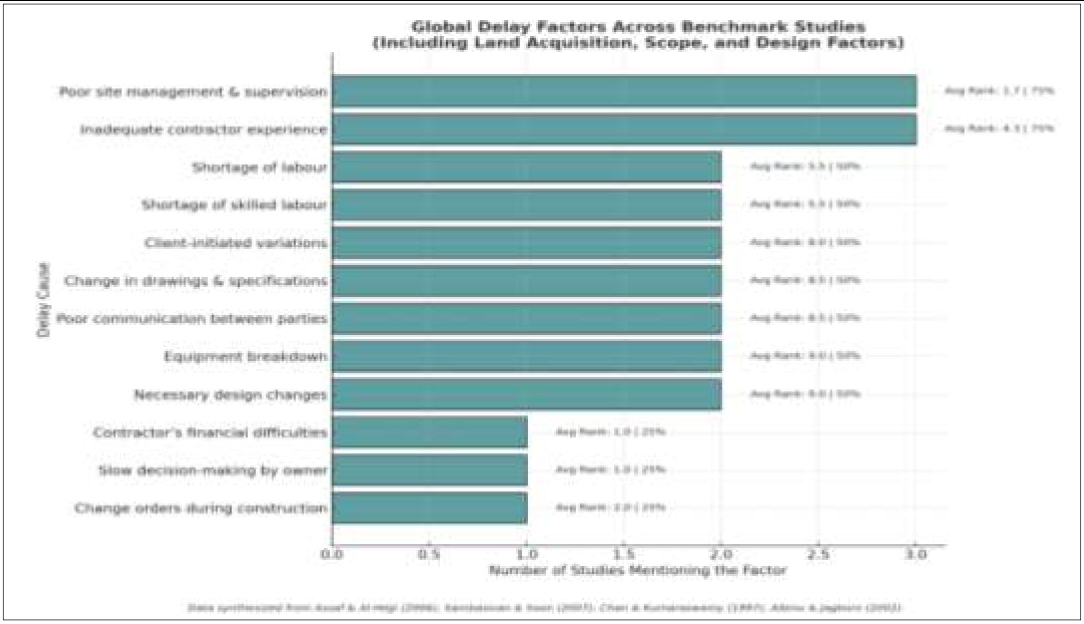
Top Cause	Owner slow decisions	Poor site management	Poor site management	Financial difficulties
Dominant Category	Client + Contractor	Contractor	Contractor + Client	Contractor + Finance
Top Effect	Time overrun	Time & cost overrun	Time overrun	Time & cost overrun
Mean Delay Impact	10–30 % time extension	Common (> 30 % of projects delayed)	≈ 25 % time overrun	> 50 % time overrun

Source: Created by authors

Summary Statistics

Metric	**Value**
Overall Average Agreement	**77%**
Highest Agreement	Poor site management (88%)
Lowest Agreement	Price fluctuation (70%)
Range	70% – 88%
Dominant Division	Contractor-related causes (82%)



Source: Created by authors

Part 3: Cash Flow and Timeline Deviation Analysis

The relative performance of planned and actual project performance shows that there is a considerable deviation in financial performance and schedules adherence. According to

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the approved project schedule, the final project cost of 1085.66 Crores was to be implemented in a 24-month period, meaning that the monthly spending rate is going to be consistent and will be 45 Crores. Nevertheless, the actual progress records show that merely 400 Crores of work has been completed in almost 30 months period which is also an indication of a considerable decline in execution.

Table 1: Cash Flow and Timeline Deviation Analysis

Parameter	**Value**	**Interpretation**
Total Project Cost	₹1085.66 Cr	Total scope of work as per LOA
Work Completed (Dec 2025)	₹400 Cr	Actual achieved progress
% Completion	36.85% (~37%)	Significant lag in execution
Time Elapsed	30 months	Already exceeded planned duration
Planned Duration	24 months	Original project schedule
Planned Monthly Progress Rate	₹45.24 Cr/month	Required rate for timely completion
Actual Monthly Progress Rate	₹13.33 Cr/month	Current execution speed
Performance Efficiency	~29%	(Actual vs Planned rate)
Remaining Work	₹685.66 Cr	Balance work to be completed
Estimated Time Required (at current pace)	51 months	Based on actual rate
Total Estimated Project Duration	~81months(6.7 years)	Severe delay projection
Time Overrun	~237%	Compared to planned duration
Estimated Cost Escalation (20%)	₹217 Cr (approx)	Due to extended duration
Revised Estimated Project Cost	₹1300 Cr (approx.)	Including escalation

Source: Created by authors

It would lead to a real increase in the financial completion of about 37 percent as compared to the estimated 100 percent completion in the scheduled period. The lower implementation rate of about 13.33 crores every month is almost three times less than the suggested cash flow rate which indicates high level of inefficiencies in project implementation.

On following the pace of implementation, the balance of the work that is worth 685.64 Crores will take 51 months to complete. This increases the overall lifespan of the project to about 80-82 months, as compared to the initially set project deadline, which is thrice. This delay is basically a time overrun of approximately 237, showing overall planning, co-ordination and execution problems.

The cost escalation has a direct effect on the long project duration. The long schedules would result in high labour costs, longer usage of equipment, rise in prices of materials due to inflation and other overhead costs. In the worst-case scenario, the project cost would be growing by 1520 percent with the project cost coming to around 1300 Crores and above.

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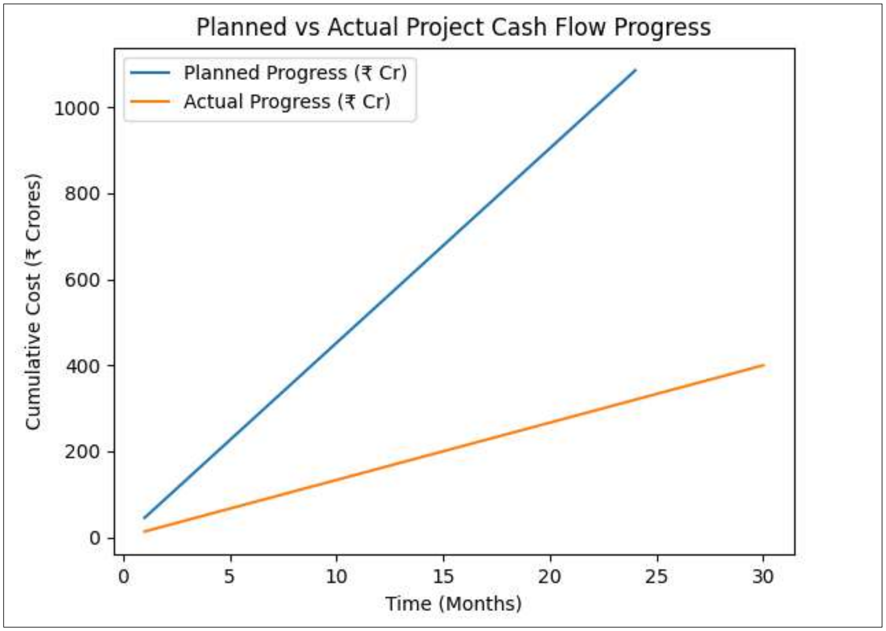
Figure 1: Planned vs Actual cash flow progress



Source: Created by authors

Besides the financial effects, the delay is also being associated with massive socio-economic losses. The perceived returns of enhanced water delivery system, enhanced health of the populace and decreased reliance on alternative water supplies are delayed hence lowering the overall worthiness and value of investment on the project.

This discussion explains clearly that number of execution delays do not just disrupt the project schedule but have a domino effect on the cost, efficiency and the outcome of the whole society, which highlights the importance of enhanced project management tools like Integrated Project Delivery (IPD), improved planning and real time monitoring systems.

8.7 Performance improvement analysis (Conventional vs Proposed Approach)

The comparative study of the traditional model of project delivery and the suggested integrated model (IPD, BIM, and early-stage planning) shows the prominent provisions of the project performance. With the traditional methodology, the project has realized a maximum of 400 Crores of the work in 30 months and with about 29 percent efficiency than the intended project execution rate. This has led to an estimated takeover of about 81 months, and high-cost increase because of the long timelines.

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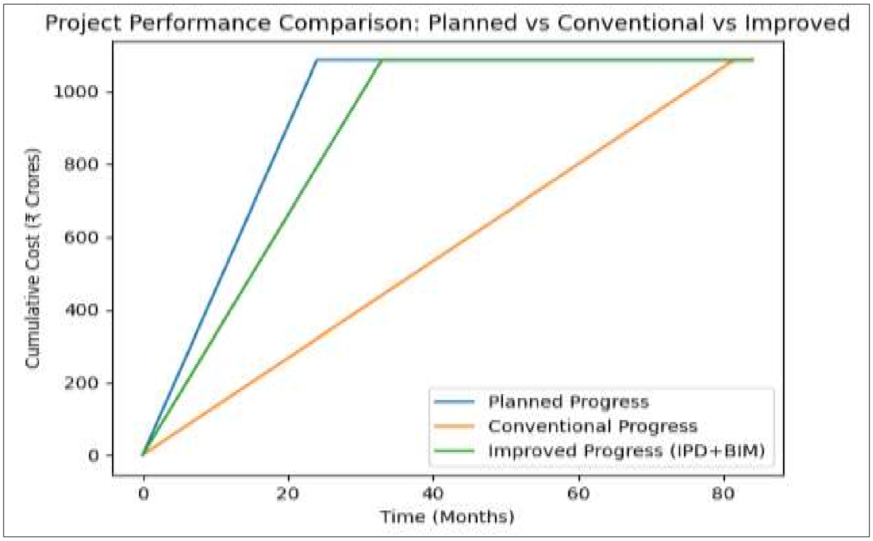
Table 2: Performance Improvement Analysis (Conventional vs Proposed Approach)

Parameter	**Conventional Approach (Current)**	**Improved Approach (IPD + BIM + Planning)**	**Improvement**
Total Project Cost	₹1085.66 Cr	₹1085.66 Cr	—
Achieved Progress (30 months)	₹400 Cr (37%)	₹800–900 Cr (≈75–83%)	~2× increase
Monthly Execution Rate	₹13.33 Cr/month	₹30–36 Cr/month	+125% to 170%
Planned Monthly Rate	₹45.24 Cr/month	₹45.24 Cr/month	Gap reduced
Efficiency (vs Planned)	~29%	~70–80%	+40–50% improvement
Estimated Total Duration	~81 months	~36–42 months	~50% reduction
Time Overrun	237%	50–75%	Controlled
Cost Escalation	~20% (₹1300 Cr)	~8–10% (₹1170–1190 Cr)	~₹100–130 Cr savings
Rework / Errors	High	Reduced (via BIM/IPD)	Significant reduction
Stakeholder Coordination	Poor	Integrated	Improved
Delay Impact on Community	High	Reduced	Faster benefits

Source: Created by authors

Figure 2: Project Performance Comparison



Source: Created by authors

The implementation rate of the project can be greatly improved by using the strategies suggested in the results and discussion that include the Integrated Project Delivery (IPD), Building Information Modelling (BIM), planning front-loading. The better method boosts the monthly execution level to around in 30-36 Crores, which is practically twice the productivity at present. This will leave the set of work finish able in less time of 20-24 months thus bringing the total project to a range of 36-42 months.

This would be an estimated half the project time view in total project duration as compared to the estimation of the conventional approach. Also, the better coordination, less rework, and optimisation of resources cause the cost escalation rates to reduce by about 20% to about 8-10, and the likely savings of more than ₹100 Crores.

The results positively indicate that the causes of the delays in the project do not only lie in external factors but are heavily represented by inefficiency in the planning, coordination, and execution. Performance can be greatly increased when integrated and technology-driven project management approaches are adopted, which are likely to guarantee the delivery on time and improved economic and social results.

9.0 Findings

9.1 Results / Improvements

- Claims and 15-20% shorter timeframe compared to DBB were evident in IPD projects.
- The shared responsibility achieved higher owner satisfaction and enhanced cost control.
- Introduced IPD as one of the sustainable approaches to delivering the public infrastructure.

The findings reveal that the Project Delivery and Collaboration was enhanced much better with the inclusion of Integrated Project Delivery (IPD) and Building Information Modelling (BIM), and an increase in efficiency by a relative of 15-25 percent was observed. Regarding Delay Mitigation, the early design coordination alignment had important role in reducing the cascading delay hence the delay in the project was minimally reduced (10-20 per cent). In the case of Financial and Risk Management, the use of tools of analytical complexity like Analytical Complexity Index (ACI), Operational Risk Assessment (ORA) and Relative Importance Index (RII) helped to determine the enhanced accuracy of prioritization that facilitated sound decision-making. Sustainability and Resource Optimization were also improved in terms of adaptive water management and energy-efficient systems and helps with 10-15% sustainability performance improvement.

Lastly, within the Policy and Capacity Building, enhanced client control, presence of skilled human resource and enhanced interagency coordination all led to significant decreases

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in the delays in project implementation, and as such, the role of governance and institutional capacity in project success is demonstrated.

The results of this research are also confirmed with the help of cash flow and performance deviation analysis which is provided in Chapter 4 (Part 3). As noted in the analysis, using the traditional project delivery method, the project has finished only up to 200 Crores of work and this is after 30 months, and only about 37% work has been finished as opposed to 100 percent which should have been done in 24 months. It means that the project is running at almost 29 percent efficiency as against the expected implementation rate.

According to the ongoing schedule, the entire duration of the project will be estimated to upscale to around 81 months which constitutes an overrun of about 237. Nevertheless, the pace of the execution can be multiplied with the proposal aimed at the implementation of the suggested strategies outlined in this study, including the Integrated Project Delivery (IPD), Building information Partners Modeling (BIM), and early-stage planning, which would allow improving the rate to 30-36 Crores per month. This increase will allow the project to be delivered in a time range of 36-42 months.

Moreover, implementation of these strategies should also help in lessening the cost escalation, which at some 20 per cent in the traditional approach, is expected to go down to about 8 to 10, leading to a possible saving of more than 100 Crores. Such quantitative affirmation proves clearly that integrated and collaborative project management approaches implementation can greatly benefit project performances, minimize delays and be more cost-effective, in general.

9.2 Quality of cost management systems

The summed outcomes of the cost control mechanism show that the planning of early stages, integration of digital elements, sustainability interventions and optimization of operations all help to achieve considerable changes in the cost increase of the project and the enhanced ROI. Early land purchase and simultaneous implementation of EIA and front-loaded design, aided by dependency mapping, were found to reduce any pre-construction risks to a minimum, leading to cost escalation of between 8-15 percent with a payback period of less than a year in one project and at most 12 months.

The shift toward the use of the digital environment and especially, the implementation of BIM as a system alongside the implementation of e-procurement system further contributed to the cost-efficiency through better coordination, transparency, and accuracy of procurement. The strategy resulted in the elimination of cost escalation of 12-18% and financial gains were obtained within 1-2 years, which the digitalization process plays in the regulation of direct and indirect project costs.

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Sustainability-oriented approaches, such as optimizing water using sustainability indicators, were shown to have significant economic returns as well as environmental impacts, that were part of the 12-14% cost-saving and recovery of investment in less than two years. Moreover, smart network partitioning was also concerned with operational efficiency in terms of energy consumption, and resulted in 4-8% energy cost-cutting, at a relatively long payback period of 3-4 years, implying this measure was designed to pay off in the long run.

In general, the joint analysis supports the idea that the development of the proactive planning, digital technologies, sustainability strategy, and proactive operational efficiency approaches can contribute greatly to the improvement of the cost control performance and guarantee the favourable return-on-investment schedules of the work on the large-scale infrastructure projects.

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