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# Delay Factors and Schedule Recovery in Urban Super Speciality Hospital Construction: A Survey and Microsoft Project Case Study from Mumbai

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***Abstract***
*Super speciality hospitals on crowded urban sites rarely open on time, yet most delay studies rank causes from opinion alone. This paper links a practitioner survey with the planning record of a delayed project. Twenty-seven delay factors, drawn from recent literature and a pilot study, were rated on a five-point scale by 19 professionals working on hospital and high-rise projects in the Mumbai Metropolitan Region (513 ratings, Cronbach's α = 0.723) and ranked with the Relative Importance Index (RII). Drawing revision (RII 0.968), design changes during execution (0.958), limited working space (0.947), late finalisation of specialist agencies (0.926) and poor inventory management (0.905) headed nine high-importance factors, and design and documentation was the strongest group. The Microsoft Project (MSP) master schedule of the Phase I expansion of a cancer hospital in Mumbai (1,136 tasks, three extension of time submissions) was then examined. The forecast opening date slipped by 575 days across seven update windows with no window of recovery, and the time-based schedule performance index had dropped to about 0.68 six months before the contractual finish. At the second extension stage, two near-equal branches, finishing and commissioning, met at the final fire NOC, so speeding up either branch alone gained nothing. Nine logic-level corrective measures tested on a validated network recovered 35 days, and an estimated 202 days (151 to 252) of the earlier slippage could have been avoided by proactive planning. A plan, monitor and control framework built on standard MSP functions is proposed for similar projects.*

***Keywords:*** *Construction delay, Hospital projects, Relative importance index, Microsoft Project, Critical path, Schedule recovery*

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## I. Introduction

Late completion is probably the most familiar failure in construction, and also one of the most studied. A project is usually said to be delayed when it, or one of its contractual milestones, finishes after the date fixed in the contract or the approved programme. Large syntheses published in the last few years show that the problem has not eased. Pooled survey evidence points again and again to client change orders, late payment, slow decisions and weak site management [1], and a review of 70 studies from 33 developing countries found the same groups of causes, often reported without any statement of project type, phase or contract form [2]. A PRISMA comparison of 92 studies from 35 countries adds that causes shift with country and project type, although owner finance and late payment appear almost everywhere [3]. When causes are traced by phase, about four in five arise during construction rather than design or procurement [4]. Recent national studies from Iraq, Afghanistan and India tell a similar story, with slow consultant reviews, weak site management, material supply and contractor inefficiency at the top of their rankings [5–8].

Hospitals sit at the hard end of this spectrum. A super speciality hospital combines a multi-storey frame with an unusual density of building services, clean rooms, medical gases, radiation shielding and specialist equipment, all of which must be designed, procured, installed, tested and certified before the first patient arrives. Healthcare projects in India and other developing countries miss their schedules largely because of design-stage uncertainty and late decisions [9], and in Saudi Arabia change orders and poor estimates were the strongest contributors in a sample of 100 delayed healthcare projects [10]. Design changes, slow decisions and complex equipment also drive cost overruns in public hospitals [11], while the contract form decides how such events are recognised and compensated [12]. Studies of Finnish hospital projects show that late changes are best prevented at the front end, through structured involvement of users, designers and builders and a shared project culture [13–15]. The effect of change on site is well documented: rework born of design errors is one of the

costliest forms of waste [16], change-order management explains a large share of project performance [17], and poor communication between parties feeds directly into overruns [18].

On the methods side, the Relative Importance Index (RII) remains the usual way of ranking delay factors because it is simple and transparent [19]. It measures perception, though, and several reviewers have asked for rankings to be tested against objective project records [2, 4]. Forensic delay analysis offers that record: windows analysis performs well on complex projects [20], newer modified-schedule methods improve on as-planned versus as-built comparisons [21], and recent taxonomies show how strongly the result depends on the quality of the contemporaneous schedule [22, 23]. Earned schedule metrics give earlier warning of slippage than cost-based indicators [24, 25], the Last Planner System supports reliable short-term planning and can be tied to earned value [26–28], and digital monitoring and machine-learning models now detect or predict delay from site and schedule data [29–33]. Even so, most of this work is demonstrated on hypothetical networks or outside India, and BIM-based scheduling research is still largely separate from everyday practice on Indian sites [34].

Three gaps follow. Hospital-specific delay evidence from dense Indian cities, where urban constraints and clinical complexity interact, is scarce. Survey rankings are seldom cross-checked against the schedule updates and extension of time (EOT) records of a real project. And the potential of Microsoft Project (MSP), the scheduling tool most widely available on Indian building sites, has not been expressed in days on an actual delayed hospital. This study addresses all three for the Phase I expansion of a super speciality cancer hospital in Mumbai. Its objectives are (i) to rank 27 delay factors for urban hospital projects, (ii) to trace how the project schedule slipped and what drove its critical path, and (iii) to estimate how much delay could have been recovered by corrective action and how much could have been avoided by proactive planning in MSP. Section 2 describes the method, Section 3 presents and discusses the results, and Section 4 concludes.

## II. Research Methodology

### 2.1 Research design and delay factors

A mixed-method case study design was adopted with two strands of evidence (Fig. 1). The first captures how practitioners perceive each delay factor. The second examines what actually happened on the case project, using its MSP master schedule and contractual correspondence. Delay factors were compiled from the literature, screened for relevance to a building on an urban site and supplemented with hospital and Mumbai-specific items such as installation of medical equipment, HVAC and clean room complexity, limited working space and traffic congestion. A pilot study with experienced professionals, using 21 open-ended questions, confirmed the wording and added context-specific factors such as local issues and delay in finalising special agencies. The final list contains 27 factors in five groups: design and documentation; client, consultant and contractual; contractor resources and site management; urban, regulatory and external; and hospital-specific technical systems.

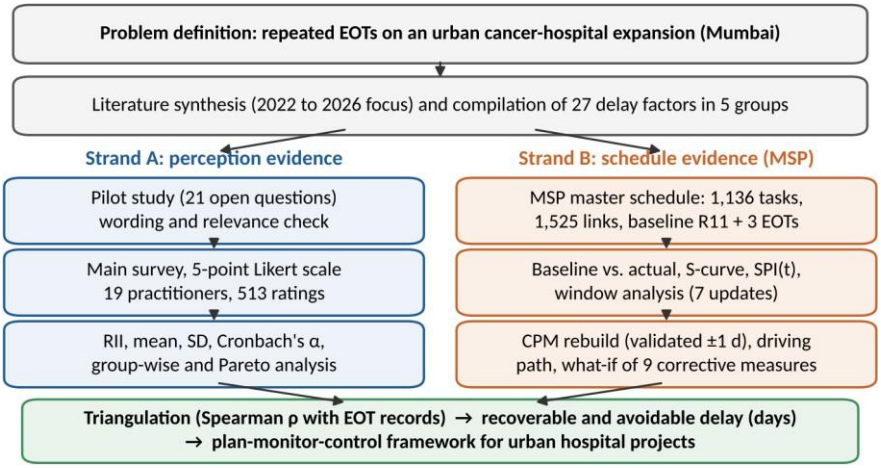



**Fig. 1** Research framework combining perception and schedule evidence

### 2.2 Questionnaire survey and statistical treatment

The main questionnaire asked respondents to rate the impact of each factor on a five-point Likert scale (1= very low to 5 = very high). It was circulated through Google Forms and in print, using purposive and snowball sampling, to clients, project management and design consultants, EPC contractors and specialist subcontractors engaged on hospital and high-rise projects in the Mumbai Metropolitan Region. Nineteen complete responses were received, giving 513 ratings with no missing values. The RII of each factor was computed as

$RII = \Sigma W / (A \times N) = (5n_5 + 4n_4 + 3n_3 + 2n_2 + n_1) / (5N)$ (1)

where W is the weight given by a respondent, A = 5 is the highest weight, N = 19 and $n_1$ to $n_5$ are the counts of each rating. Factors were classed as high (RII ≥ 0.80), high-medium (0.60 to 0.80) or medium (0.40 to 0.60). Mean score, standard deviation and Cronbach's alpha were used to judge agreement and internal consistency. To test the ranking against documentary evidence, the frequency of terms related to each factor in the three EOT submissions was counted and compared with the RII values through Spearman's rank correlation.

### 2.3 Case project and schedule data

The case project is the Phase I expansion of a private super speciality cancer hospital in the western suburbs of Mumbai, built on an operating campus under an EPC contract with nominated subcontractors for interiors, façade and selected specialist works. Its main features are listed in Table 1. The hospital, the client and all contracting organisations are kept anonymous. The MSP file analysed is the master schedule updated for the second EOT submission, which carries the February 2024 revision (R11) as its saved baseline.

**Table 1.** Profile of the case study project and its MSP master schedule

| Item | Description |
|---|---|
| Project type | Phase I expansion of a private super speciality cancer hospital |
| Building | 3 basements, ground + 11 floors and terrace; RCC core with steel frame and composite decks |
| Clinical spaces | Modular OTs, chemotherapy, dialysis, BMT and isolation rooms, radiotherapy bunker |
| Contract | EPC with nominated subcontractors (interiors, façade, specialist packages) |
| Commencement / contract finish | January 2023 / December 2024 (700 days) |
| Opening date: baseline, EOT-1, EOT-2, EOT-3 | 22-Dec-24, 13-Oct-25, 31-Mar-26, 20-Jul-26 |
| MSP schedule | 1,136 tasks; 1,525 links (1,011 FS, 497 FF, 17 SS); 238 date constraints; 7-day calendar |
| Status at EOT-2 data date (30-Sep-25) | 89% complete; 22 critical tasks |

### 2.4 Schedule analysis and recovery modelling

Baseline and current finish dates were compared for every work package. A duration-weighted S-curve was built for the 885 tasks that carry a baseline, and progress was expressed as a time-based schedule performance index,

$SPI(t) = ES / AT$ (2)

where ES is the earned schedule (the date by which the baseline expected the progress actually achieved) and AT is the actual time elapsed [24]. The forecast opening date was read from each of seven schedule updates issued between February 2024 and March 2026, and the slippage in each window was linked to the reasons the contractor recorded, following the windows approach found most suitable for complex projects [20]. To allow what-if testing, the MSP network was rebuilt as a critical path method (CPM) model using the exported durations, finish-to-start, start-to-start and finish-to-finish links with lags, constraints, actual dates and the seven-day calendar. The rebuilt model returned an opening date of 31 March 2026 against 1 April 2026 in MSP, a difference of one day. Corrective measures were then applied only to incomplete activities, without removing scope, each as a named change to a duration, lag or relationship type, and the network was rescheduled after every change. For the past windows, an avoidability factor between 0 (external events) and 0.5 (decisions a well-linked schedule would have flagged months ahead) was applied to each cause category, with a ±25% sensitivity band.

## III.Results and Discussion

### 3.2 Ranking of delay factors

The RII values range from 0.568 to 0.968, with a mean of 0.741 (Fig. 2). Nine factors fall in the high band, fifteen in the high-medium band and three in the medium band, so no factor was regarded as unimportant. The nine high-importance factors are given in Table 2. They form three clusters. The first is the flow of design information and approvals: drawing revision, design change during execution and approval of materials, mock-ups and shop drawings. The second is client-side decision making and the late appointment of specialist agencies. The third is the urban setting itself: limited working space, traffic, local issues and the difficulty of managing inventory on a site with almost no storage. The top two factors also show the closest agreement; every respondent rated them high or very high, with standard deviations below 0.45.

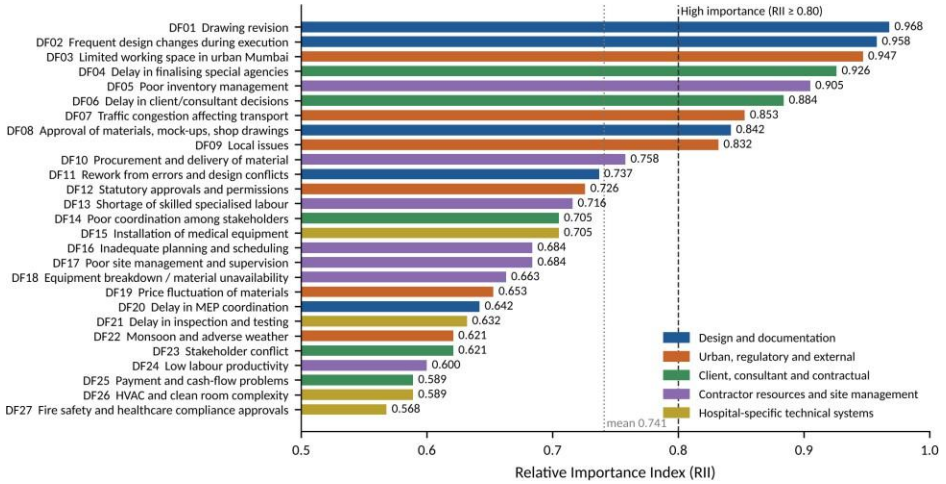



**Fig. 2** Relative Importance Index of the 27 delay factors, coloured by group

**Table 2.** Delay factors of high importance (RII ≥ 0.80)

| Rank | Code | Delay factor | Mean | SD | RII |
|---|---|---|---|---|---|
| 1 | DF01 | Drawing revision | 4.84 | 0.37 | 0.968 |
| 2 | DF02 | Frequent design changes during execution | 4.79 | 0.42 | 0.958 |
| 3 | DF03 | Limited working space in urban area of Mumbai | 4.74 | 0.56 | 0.947 |
| 4 | DF04 | Delay in finalising special agencies | 4.63 | 0.76 | 0.926 |
| 5 | DF05 | Poor inventory management | 4.53 | 1.12 | 0.905 |
| 6 | DF06 | Delay in client and consultant decision making | 4.42 | 0.69 | 0.884 |
| 7 | DF07 | Traffic congestion affecting transportation | 4.26 | 0.93 | 0.853 |
| 8 | DF08 | Delay in approval of materials, mock-ups and shop drawings | 4.21 | 1.03 | 0.842 |
| 9 | DF09 | Local issue | 4.16 | 1.21 | 0.832 |

Design change and slow decisions appear near the top of almost every study cited above [1, 9, 10]. What sets this result apart is the weight of urban factors, which take three of the nine high-importance places. Payment and cash-flow problems, unlike in many public-sector studies [3, 7], rank only joint 25th (0.589). This matches the case records, where the contractor attributes delay mainly to design information, changes and decisions rather than to client payment, and suggests that the delay profile of privately funded urban hospitals differs from that of publicly funded work.

### 3.3 Group behaviour, agreement and triangulation

Design and documentation is the most influential group (mean RII 0.829), followed by urban, regulatory and external factors (0.772); hospital-specific technical systems rank last (0.624) even though they are the most distinctive feature of the building type (Fig. 3a). Very high was the most frequent rating (206 of 513), yet all five points of the scale were used (Fig. 3b), which shows that respondents did discriminate between factors. Cronbach's alpha for the 27-item scale is 0.723, above the usual 0.70 threshold.

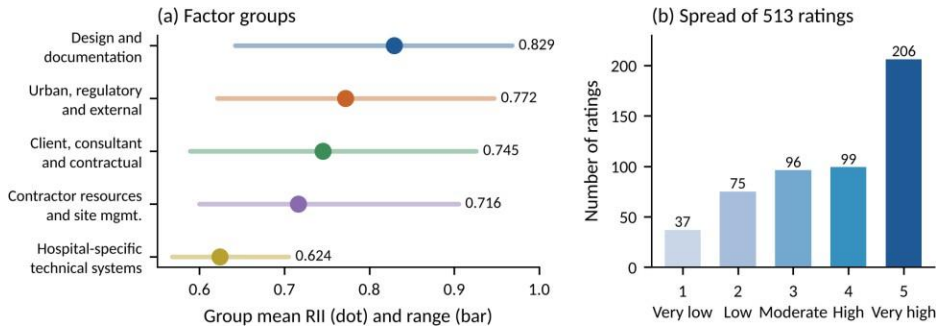



**Fig. 3** (a) Mean and range of RII for each factor group; (b) distribution of all 513 ratings

Drawing revision and design change, ranked first and second in the survey, are also by far the most frequent subjects of the EOT correspondence (122 and 149 mentions). Across all 27 factors, however, the rank correlation between RII and documentary frequency is weak ($\rho = 0.19$, $p = 0.34$). The difference is understandable. EOT letters are written to establish entitlement, so they dwell on client-side causes and say little about traffic or storage, which create no entitlement. The survey captures how the work feels to the people doing it. Both sources agree on the factors that matter most.

### 3.4 Schedule performance against the baseline

Phase I started in January 2023 with a contractual duration of 700 days. The structural frame, planned for August 2023, was completed in January 2024. Finish variance then grew along the construction sequence: about 305 days for the superstructure, 351 days for the substation and 400 to 481 days for the MEP and finishing packages, with fixed furniture the worst affected. Delay did not come from one event; each new change landed on top of the backlog left by the previous ones. The S-curve gap opened early. By 30 June 2024 the baseline called for 68% completion against about 25% achieved, and on the original completion date of 22 December 2024 the project stood at about 42%. SPI(t) was about 0.68 in June 2024, 0.63 in December 2024 and 0.60 in September 2025. In other words, the warning that the contract date could not be met was sitting in the MSP file six months before that date passed, but it was never turned into a recovery plan.

### 3.5 Window analysis of slippage

The forecast opening date moved later at every one of the seven updates, from 22 December 2024 to 20 July 2026, a slippage of 575 days against the MSP baseline (589 days against the contract). No window recovered any time (Fig. 4). The two largest windows have different characters. In W1 (105 days) the MEP drawings for the basement and lower floors arrived 116 to 145 days late, the structural drawings for Levels 7 to 10 were revised after fabrication had begun and the finishing drawings were about four months late. W6 (169 days) was driven by change: 355 new drawings and 458 site changes in ten months, reflected ceiling plans revised about four times per floor, repeated changes to the number of air handling units (117 to 104 to 99), fan coil units and LT panels, and 56 non-tendered items approved after an average of 56 days. In W7 (111 days) whole floors were converted to new clinical uses while finishing was in progress.

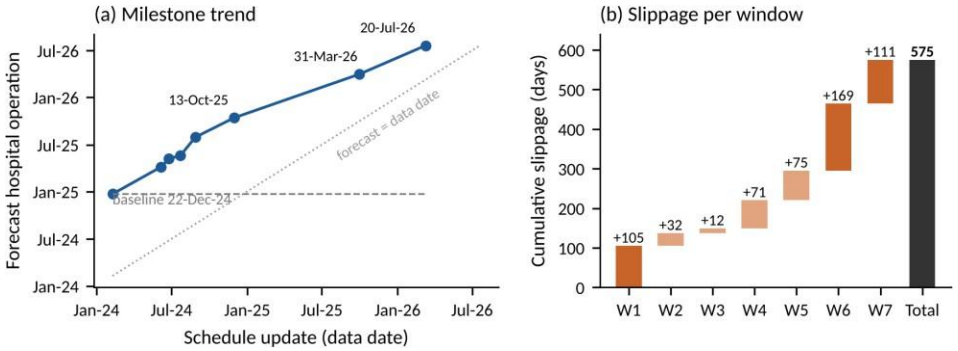



**Fig. 4** (a) Milestone trend of the forecast opening date; (b) slippage in each schedule window

### 3.6 Critical path at the second extension and corrective measures

At the data date of 30 September 2025 MSP flagged 22 tasks as critical and a further 54 incomplete tasks had ten days of total slack or less. Tracing the driving path revealed the feature that governs any recovery attempt (Fig. 5). A finishing branch, ending with floor-by-floor painting and fixed furniture, and a commissioning branch, running from extra-low-voltage (ELV) systems through a 60-day lag to commissioning, both converge on the final fire NOC within a day of each other. The occupancy certificate (OC) and consent to operate (CTO) follow in series.

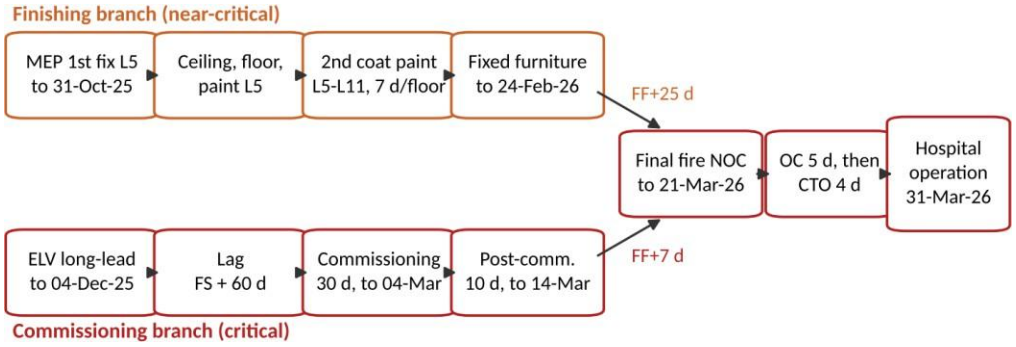



**Fig. 5** Converging driving paths to hospital operation at the EOT-2 update (data date 30 September 2025)

Nine corrective measures were defined, each tied to named MSP activities (Table 3). Duration cuts were held to about 30% of the original values, which is within what added crews can normally deliver before congestion on a floor erodes productivity, and no measure assumes an authority acting faster than its usual processing time.

**Table 3.** Corrective measures applied to the validated network (original values from the MSP file)

| Code | Measure | Parameter changed (original → revised) |
|---|---|---|
| M1 | Second painting crew for the 2nd coat | Floor-to-floor link at Level 9 removed; Levels 9 to 11 by second crew |
| M2 | Extra gangs on Level 5 ceiling and flooring | 20, 20, 15 d → 14, 14, 10 d |
| M3 | Larger painting crews, quick-drying system | Floor-to-floor FF + 7 d → FF + 4 d (Levels 6 to 11) |
| M4 | Floor-wise fire pre-inspection | Furniture to fire NOC FF + 25 d → FF + 15 d; finishes FF + 15 d → FF + 10 d |
| M5 | Factory acceptance and pre-commissioning of ELV | ELV to commissioning FS + 60 d → FS + 40 d; gas flooding FS + 45 d → FS + 30 d |
| M6 | Phased, system-wise commissioning | Commissioning 30 → 24 d; post-commissioning 10 → 7 d |
| M7 | Joint fire inspection during post-commissioning | Post-commissioning to fire NOC FF + 7 d → FF + 3 d |
| M8 | CTO processed in parallel with OC | OC to CTO FS + 0 d → SS + 2 d |
| M9 | Extra electrical gangs for third fix, Levels 10 and 11 | 20, 10 d → 14, 7 d; third fix to commissioning FF + 15 d → FF + 10 d |

Measures M1 to M4 shortened the finishing branch by about a month but did not move the opening date at all, because the commissioning branch stayed critical (Fig. 6a). The first gain came from factory acceptance and pre-commissioning of ELV systems (M5, 14 days), after which phased commissioning, joint fire inspection, parallel CTO processing and extra third-fix gangs added 3, 4, 3 and 11 days. Together the nine measures moved hospital operation from 31 March to 24 February 2026, a gain of 35 days. Tested in bundles, finishing acceleration alone and MEP-commissioning acceleration alone each recovered nothing, and only their combination released the time (Fig. 6b). Removing measures one at a time showed that M5 (19 days), M9 (11 days) and M6 (8 days) carried most of the gain. After recovery the ELV, crane-zone and furniture branches keep 1, 6 and 9 days of float, so the ELV branch remains the main residual risk.

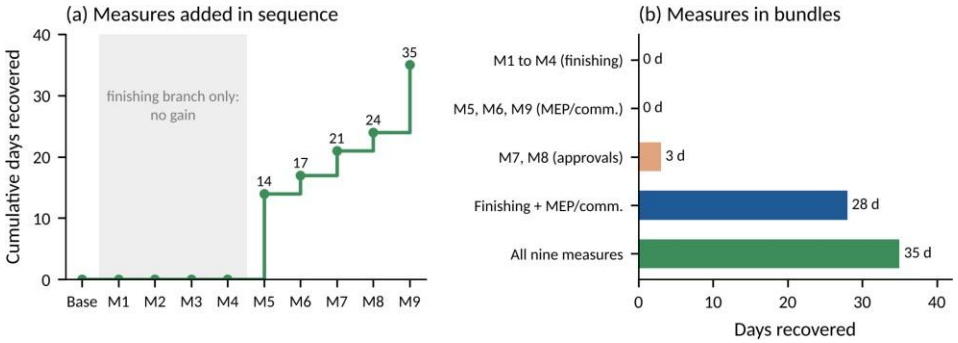



**Fig. 6** Days recovered: (a) measures added in sequence; (b) measures applied in bundles

### 3.7 Avoidable delay and the role of MSP

Late recovery has clear limits. The 35 days reduce the slippage of hospital operation against the baseline from 464 to 429 days, about 8%, because most of the delay was already built into the work by September 2025. The larger question is how much could have been prevented earlier. Distributing the 575 days among cause categories and applying the avoidability factors gives about 202 avoidable days, or 35% (range 151 to 252 days), led by late design information (78 days), client-driven changes (44 days) and late finalisation of packages and agencies (31 days) (Fig. 7). The mechanisms are ordinary MSP practice. Had each GFC drawing package been a task with a required-by date linked to the work that depends on it, late drawings would have appeared as negative float in the first week rather than as narrative in an EOT letter months later. Package award activities with need-dates would have shown the cost in days of each week of indecision, and monthly reporting of SPI(t) would have prompted recovery in mid-2024.

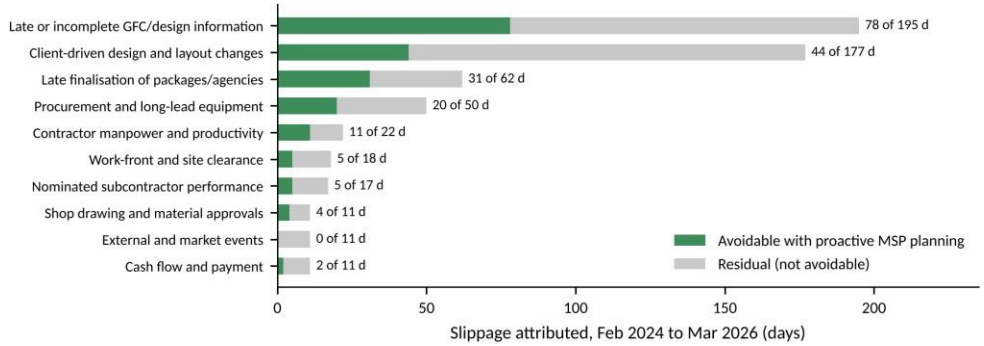



**Fig. 7** Slippage attributed to each cause category and the share avoidable through proactive MSP planning

These findings are gathered into a plan, monitor and control framework (Fig. 8). Every element uses functions already present in MSP, such as deadlines, total slack, the saved baseline, tracking Gantt views, multiple critical paths and custom calendars, so it can be adopted on any project that already schedules in MSP without new software. It also fits naturally with look-ahead planning [26, 28] and with the digital monitoring tools now emerging [29, 30].

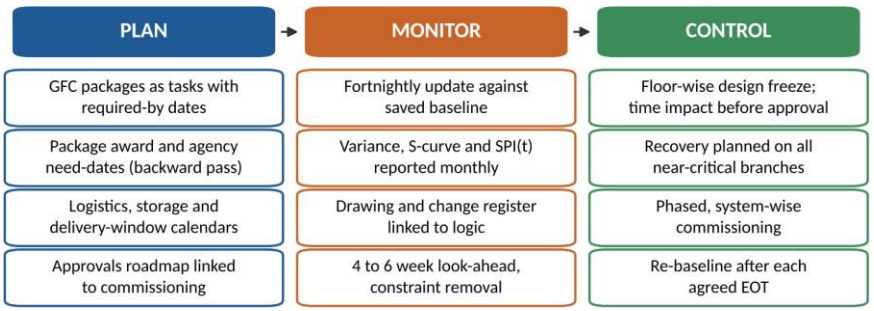



**Fig. 8** Plan, monitor and control framework for delay management on urban hospital projects

## IV.Conclusions

This study combined a practitioner survey with the MSP record of a delayed super speciality hospital in Mumbai. The main conclusions are as follows.

- Drawing revision (RII 0.968), design change during execution (0.958) and limited working space (0.947) are the leading delay factors for urban hospital projects, and nine of 27 factors are of high importance. Urban factors are far more prominent than in most international studies, while payment problems rank low on this privately funded project.
- The case project slipped 575 days against its baseline over seven windows with no recovery in any of them. An SPI(t) of about 0.68 gave a clear warning six months before the contract date.
- Near completion, two branches of almost equal length converged on the fire NOC. Nine coordinated measures recovered 35 days, whereas accelerating either branch alone recovered none; recovery has to be planned across all converging paths.
- About 202 days (151 to 252) of the slippage, roughly one third, could have been avoided by linking design deliverables and package awards into the schedule and acting on variance signals in time.

The survey sample of 19 is modest and the schedule evidence comes from a single project, so the figures are indicative and the avoidability factors rest on stated judgement. Extending the survey across several hospitals

and linking schedule updates to 4D or delay-prediction models are natural next steps.

**Declarations**

**Ethics approval and consent to participate**

Participation in the survey was voluntary and anonymous, and respondents agreed to take part before answering. Project documents were used with the permission of the project management team, and no organisation or individual is identified.

**Consent for publication**

Not applicable.

**Availability of data and materials**

The survey dataset and RII calculation workbook are available from the corresponding author on reasonable request. The project schedule and correspondence are confidential and cannot be shared.

**Competing interests**

The authors declare that they have no competing interests.

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Not applicable. This research received no external funding.

**Authors' contributions**

Author 1: literature review, questionnaire design, data collection, survey and schedule analysis, original draft.
Author 2: conceptualisation, supervision, methodology, review and editing.

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