

# Retrospective Delay Analysis Techniques in Multi-Storey Office Buildings

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**Abstract** - This study examines construction delays in multi-story office building projects and evaluates the effectiveness of major retrospective delay analysis techniques, including As-Planned vs. As-Built Analysis, Window Analysis, Retrospective Time Impact Analysis (TIA), and Collapsed As-Built Analysis. Through literature review, comparative journal analysis, and case studies of commercial office projects, the research analyzes global delay factors and compares the techniques based on accuracy, data requirements, handling of concurrent delays, and practical applicability. The findings show that simpler methods are easier to apply but less effective in analyzing dynamic critical paths and concurrency, while advanced methods provide greater accuracy but require extensive project data. The study concludes that no single technique is suitable for all project conditions, as method selection depends on project complexity, data availability, and analysis objectives, especially in dispute resolution. To address this, a hybrid delay analysis framework is proposed to improve accuracy, transparency, and reliability in construction delay assessment.

**Key Words:** Construction delay analysis; Retrospective delay analysis; Time Impact Analysis (TIA); Window Analysis; Collapsed As-Built; Concurrent delays; Construction project management.

## 1. INTRODUCTION

Construction delays remain a major challenge in the delivery of multi-storey office building projects, often leading to cost overruns, schedule extensions, and contractual disputes. The increasing complexity of projects, combined with multiple stakeholders and interdependent activities, makes accurate delay identification and responsibility allocation difficult. Delays typically arise from factors such as financial constraints, poor planning, material shortages, design changes, and coordination issues. These challenges are further complicated by concurrent delays and shifting critical paths, limiting the reliability of conventional assessment approaches. To address this, several delay analysis techniques such as As-Planned vs. As-Built, Window Analysis, Time Impact Analysis (TIA), and Collapsed As-Built (But-For) are widely used. However, these methods differ in accuracy, data requirements, and applicability, and no single technique is universally suitable.

## 2. METHODOLOGY

This study adopts a structured approach combining literature review, comparative analysis, and case study application to evaluate retrospective delay analysis techniques in multi-storey office building projects. An extensive literature review is first conducted to identify key methods As-Planned vs. As-Built, Window Analysis, Time Impact Analysis (TIA), and Collapsed As-Built and to examine their characteristics, limitations, and common delay factors. A comparative framework is then developed to assess these techniques based on criteria such as data requirements, analytical complexity, ability to handle concurrent delays, treatment of critical path changes, and overall accuracy. The selected methods are subsequently applied to both simulated and real-world case studies using project schedules, progress records, and delay data.

Each technique is tested on the same dataset to evaluate variations in delay estimation and responsibility allocation. The results are then synthesized to develop a hybrid delay analysis framework that integrates the strengths of multiple techniques, providing practical guidance for selecting appropriate methods based on project conditions.

## 3. LITERATURE STUDY- DELAY ANALYSIS TECHNIQUES

Construction delays have been extensively studied in the field of construction project management, with research consistently identifying them as a major cause of cost overruns, time extensions, and contractual disputes. Delays are influenced by a combination of financial, technical, managerial, and external factors, reflecting the complex and interdependent nature of construction projects. Studies across different regions indicate that financial difficulties, delayed payments, poor planning and scheduling, material shortages, design changes, and inadequate coordination among stakeholders are among the most significant contributors to project delays. These findings highlight that delays are not caused by isolated issues but rather by a network of interacting factors that vary depending on project type, location, and stakeholder involvement.

It address the challenges associated with delay identification and quantification, various delay analysis techniques (DATs) have been developed. Among the most commonly used methods are As-Planned vs. As-Built Analysis, Window Analysis, Time Impact Analysis (TIA), and Collapsed As-Built (But-For) Analysis. The As-Planned vs. As-Built method is one of the simplest approaches, comparing baseline schedules with actual project performance to determine overall delay. While it is easy to apply and requires minimal data, it does not adequately consider causation, concurrency, or changes in the critical path, which limits its reliability in complex projects.

More advanced methods, such as Window Analysis, provide a dynamic approach by dividing the project timeline into multiple intervals and assessing delays within each window. This allows for better identification of critical path changes and concurrent delays over time, making it more suitable for complex and evolving projects. However, the method requires detailed and consistent project records, and its accuracy depends heavily on the selection of appropriate time windows and the availability of updated schedules.

Time Impact Analysis (TIA) is widely recognized for its ability to evaluate the effect of individual delay events by inserting them into the project schedule. This method is particularly useful in prospective and retrospective analyses, as it provides a logical and structured way to assess the impact of delays on project completion. Despite its strengths, TIA requires comprehensive and reliable data, as well as expertise in schedule modelling, which may limit its practical application in projects with poor documentation.

The Collapsed As-Built (But-For) Analysis offers a retrospective approach by reconstructing the as-built schedule and removing specific delay events to determine how the project would have progressed in their absence. This method is considered highly effective in identifying compensable delays and allocating responsibility, particularly in dispute resolution scenarios. However, it is data-intensive and relies on accurate reconstruction of project logic, making it complex and time-consuming.

Comparative studies indicate that no single delay analysis technique is universally applicable, as each method has distinct strengths and limitations depending on project conditions, data availability, and analysis objectives. Research also highlights that different techniques can produce varying delay durations and responsibility allocations when applied to the same project, raising concerns about consistency and reliability.

This variability underscores the importance of selecting an appropriate method based on specific project requirements rather than relying on conventional practices.

Despite the extensive body of literature on delay analysis, significant gaps remain. Many studies focus on theoretical comparisons without sufficient validation through real-world applications, limiting their practical relevance. Additionally, there is a lack of standardized criteria for selecting delay analysis techniques, particularly in situations involving incomplete or uncertain data. These gaps indicate the need for a more structured and practical approach to method selection.

In response to these limitations, recent research has begun to explore the integration of multiple delay analysis techniques to improve accuracy and reliability. Hybrid approaches that combine the strengths of different methods have shown potential in addressing the limitations of individual techniques, particularly in complex projects with multiple overlapping delays. However, further research is required to develop and validate such frameworks in real-world scenarios.

## 4. CASE STUDIES

The study includes both live and literature-based case studies:

Indian Case Studies:

- Workez, Bangalore
- Awfis, Bangalore

These case studies analyse and study about the pros and cons of the various delay analysis techniques

### 4.1. Case Study

The live case studies of Workez and Awfis office projects in Bangalore were analyzed together to evaluate the performance of retrospective delay

Analysis techniques under real construction conditions. Both projects represent multi-storey commercial office developments with similar complexity, involving structural works, interior fit-outs, and MEP installations. The projects experienced multiple delays due to recurring factors such as design changes, delayed approvals, material shortages, coordination issues, and scheduling inefficiencies, which are consistent with global delay trends identified in the literature. These similarities allowed for a comparative and consolidated analysis of delay behavior across projects.

Comprehensive project data, including baseline schedules, updated programs, delay registers, and progress reports, were collected and examined. The As-Planned vs. As-Built method was initially applied to both projects, providing a clear indication of total project delay. However, the method lacked the ability to account for concurrent delays and shifting critical paths, resulting in an oversimplified interpretation of delay responsibility. Time Impact Analysis (TIA) was then used to evaluate the effect of individual delay events by inserting them into the schedule. Its reliability depended heavily on data accuracy and modeling assumptions, particularly in scenarios involving overlapping delays.

Window Analysis proved to be more effective in both projects by segmenting the timeline into multiple intervals and capturing the evolution of delays over time. It successfully identified changes in the critical path and highlighted instances of concurrent delays involving both contractor and client-related factors. The Collapsed As-Built (But-For) method further enhanced the analysis by isolating delay events and determining their impact on project completion. This approach provided the most clarity in distinguishing compensable, non-compensable, and concurrent delays, making it particularly useful for dispute resolution.

The combined analysis revealed that different techniques produced varying delay durations and responsibility allocations when applied to the same datasets. Simpler methods tended to overestimate delays and lacked analytical depth, whereas advanced methods provided more accurate and defensible results but required extensive documentation and expertise. Both case studies also highlighted the critical role of data quality, as incomplete or inconsistent records significantly affected the accuracy of advanced techniques.

From an analytical perspective, the findings confirm that delay analysis is highly context-dependent, and no single method is universally suitable for all project scenarios. The variation in results underscores the importance of method selection based on project complexity, availability of data, and purpose of analysis. The study also demonstrates that delays are rarely isolated events but occur as interconnected and concurrent issues that evolve over the project lifecycle.

Based on these findings, several key recommendations are proposed. First, maintaining accurate and regularly updated project schedules, along with detailed delay documentation, is essential for reliable delay analysis. Second, advanced techniques such as Window Analysis and Collapsed As-Built should be adopted for complex projects where concurrency and critical path changes are significant. Third, a hybrid approach combining multiple techniques is recommended to balance simplicity and analytical accuracy. Additionally, proactive project management practices, including timely decision-making, improved coordination, and better planning, are necessary to minimize delay occurrence. Finally, enhancing practitioner expertise in delay analysis methods and scheduling tools will improve the consistency and credibility of delay assessments.

Overall, the combined case study analysis validates the theoretical framework of this research and demonstrates that integrating multiple delay analysis techniques provides a more accurate, transparent, and defensible approach to evaluating construction delays in multi-storey office building projects.

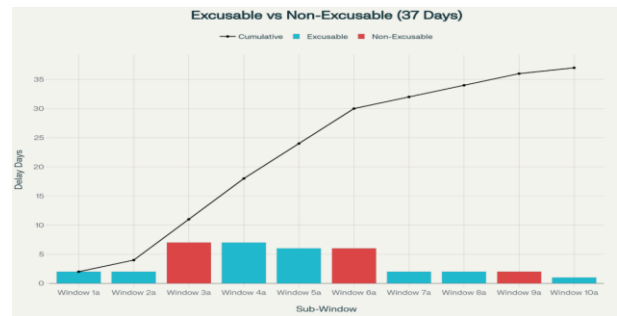


Chart 1:- DAT 1

The figure presents the distribution of excusable and non-excusable delays across project time windows, along with the cumulative delay progression. Each window represents a specific phase of the project, while the bars indicate delay type and magnitude, and the line shows total accumulated delay.

The results indicate that delays are concentrated in the middle project stages, particularly in Windows 3a to 6a. Non-excusable delays dominate in some windows, suggesting contractor-related issues, while excusable delays in others indicate external or client-driven factors such as design changes or approvals. The cumulative delay curve rises sharply during these stages, showing their significant impact on overall project delay.

The variation in delay types across different windows highlights the dynamic nature of construction projects and demonstrates that delays do not occur uniformly throughout the project lifecycle. Instead, they fluctuate depending on project activities, stakeholder decisions, and site conditions during each stage. In later stages, delay increments reduce, indicating improved control or stabilization. Overall, the graph demonstrates that delays occur unevenly over time and highlights the importance of distinguishing delay types for accurate analysis and responsibility allocation.

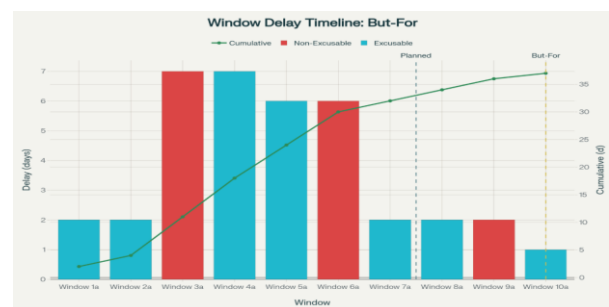


Chart 2:- DAT 1

The figure shows a window-based delay analysis using the But-For method, with bars representing excusable and non-excusable delays and the line indicating cumulative delay over time.

Most delays occur in the mid-project windows (3a-6a), where both delay types are significant, causing a sharp rise in cumulative delay. Non-excusable delays indicate contractor-related issues, while excusable delays reflect external factors. The dashed lines mark the planned completion and But-For completion, with the gap representing the net delay impact. In later stages, delays reduce and the curve stabilizes, indicating improved project control.

#### 4.2. RESULT & DISCUSSION

The combined analysis of the Workez and Awfis live case studies demonstrates that the application of different delay analysis techniques results in significant variation in both delay quantification and responsibility allocation. The As-Planned vs. As-Built method provided a clear overview of total project delay in both cases; however, it consistently overestimated delay impacts and failed to account for concurrent delays and dynamic changes in the critical path. This confirms its limitation as a purely observational tool that is better suited for preliminary assessments rather than detailed forensic analysis.

Time Impact Analysis (TIA) improved the evaluation by enabling the assessment of individual delay events through schedule modeling. It was particularly useful in identifying the effect of design changes and approval delays on project timelines. However, its effectiveness was constrained by the quality of available data and the subjectivity involved in modeling assumptions, especially in situations where multiple delays overlapped. In contrast, Window Analysis proved to be more reliable in capturing the evolving nature of project delays. By analyzing delays within defined time intervals, it effectively identified shifts in the critical path and provided a clearer understanding of concurrent delays across different project stages.

The Collapsed As-Built (But-For) method produced the most detailed and defensible results by isolating delay events and evaluating their direct impact on project completion. It enabled clearer differentiation between compensable, non-compensable, and concurrent delays, making it particularly suitable for dispute resolution. However, its application required extensive and accurate project records, as well as significant analytical effort.

The comparative results highlight that advanced techniques such as Window Analysis and But-For Analysis offer greater accuracy and reliability, particularly in complex projects with multiple overlapping delays. Nevertheless, these methods are resource-intensive and depend heavily on data quality. Simpler techniques, while easier to implement, lack the analytical depth required for precise delay assessment. The findings therefore reinforce that no single technique is universally applicable, and the choice of

method must be aligned with project complexity, data availability, and the purpose of analysis.

Overall, the study supports the adoption of a hybrid approach that combines the strengths of multiple techniques. Such an approach enables a balanced evaluation by using simpler methods for initial assessment and advanced techniques for detailed analysis, thereby improving accuracy, transparency, and credibility in delay assessment and dispute resolution

Criteria	As-Planned vs As-Built	Collapsed As-Built (But-For Analysis)	Window Analysis	Retrospective Time Impact Analysis
Basic Concept	This method compares the originally planned schedule with the actual as-built schedule to identify overall project delays.	This method removes delay events from the as-built schedule to evaluate how the project would have progressed without those delays.	This method divides the project duration into time windows and analyzes delays within each period to capture their impact over time.	This method introduces delay events into the baseline schedule retrospectively to determine their effect on project completion.
Accuracy	This method has low accuracy because it does not consider changes in project logic or sequencing.	This method provides good accuracy as it isolates and evaluates the effect of specific delay events.	This method offers very high accuracy as it reflects the dynamic nature of project progress and critical path changes.	This method provides moderate accuracy depending on the reliability of assumptions and baseline data.
Handling of Concurrent Delays	This method does not effectively distinguish or analyze concurrent delays.	This method can identify concurrent delays to some extent by analyzing the impact of removed events.	This method effectively analyzes concurrent delays by examining them within defined time windows.	This method can analyze concurrent delays, although results depend on the accuracy of modeling.
Data Requirement	This method requires minimal data, mainly the planned and as-built schedules.	This method requires detailed as-built data and accurate identification of delay events.	This method requires extensive and continuous project records for each analysis window.	This method requires a reliable baseline schedule and detailed delay event information.
Legal Acceptance	This method has moderate acceptance but may be challenged due to its simplicity.	This method has strong legal acceptance as it demonstrates cause-and-effect relationships.	This method has very high legal acceptance and is widely used in dispute resolution.	This method has moderate legal acceptance but is sometimes less preferred than window analysis.
Best Use Case	This method is best suited for preliminary delay assessment and general comparison.	This method is best suited for claims analysis to evaluate scenarios without specific delays.	This method is best suited for detailed forensic delay analysis in disputes.	This method is best suited for assessing the impact of multiple delay events retrospectively.

Chart 3:- Comparison Table - DAT

#### CONCLUSION

This study critically evaluated major retrospective delay analysis techniques As-Planned vs. As-Built, Time Impact Analysis (TIA), Window Analysis, and Collapsed As-Built (But-For) to assess their effectiveness in analyzing delays in multi-storey office building projects. Through a combination of literature review and live case

Study application, the research demonstrates that Construction delays are complex, multi-causal, and highly dependent on project-specific conditions, making accurate delay assessment both essential and challenging.

The findings confirm that each delay analysis technique has distinct strengths and limitations. Simpler methods such as As-Planned vs. As-Built are useful for preliminary assessments due to their ease of application but lack the analytical depth required to address concurrency and dynamic critical path changes. In contrast, advanced methods such as Window Analysis and Collapsed As-Built provide more accurate and defensible results, particularly in complex projects, but require extensive data, consistent documentation, and expert interpretation. Time Impact Analysis offers a balanced approach but remains sensitive to modeling assumptions and data quality.

The live case studies further highlight that different techniques can produce varying delay durations and responsibility allocations when applied to the same project, emphasizing that method selection significantly influences outcomes. This variability reinforces the conclusion that no single technique is universally applicable for all project scenarios.

To address this limitation, the study proposes a hybrid delay analysis approach that integrates the strengths of multiple techniques. Such an approach enables more accurate, transparent, and reliable delay assessment by combining initial observational analysis with detailed modeled evaluation. Ultimately, this research contributes to construction project management by providing a structured framework for selecting appropriate delay analysis techniques, thereby improving decision-making, minimizing disputes, and enhancing the overall effectiveness of delay analysis in complex construction projects.

**Table 2-: Comparison Table – DAT**

Aspect	As-Built/Actual	Collapsed	Window	RTK
Practicality	Very High Simple calc. min resources	Medium Needs schedule skills	Medium Periodic updates needed	Low Subjective, forensic recon
Data Req.	Low Baseline & as-built dates	High As-Built, activity records	Very High Multi data sources req'd	Very High CPM, logic, logs, reports
Complexity	Very Low Basic arithmetic	High Complex reconstruction	High Multi variables, windows	Very High Report modeling
Accuracy	Low Ignores CRT path	High Uses actual data	Very High Real-time CRT path	Variable Depends on execution
Primary Use	Quick assessment Simple projects	Forensic analysis Legal disputes	Complex projects Claims mgmt.	Legal disputes Expert testimony
Float	Not Considered As-Built analysis	Actual Float As-Built CRT path	Dynamic Tracks changes	Theoretical Float consumption
Concurrent	Not handled No identification	Limited Hard to model	Excellent For window capture	Subjective Analyst judgement
Time	Very Fast Minutes to hours	Slow Days to weeks	Very Slow Weeks to months	Very Slow Weeks to months
Cost	Very Low Minimal time	High Expert schedulers	Very High Resource intensive	Very High Expert modeling

**Table 3-: Comparison Table –RTIA,But-for and Window Analysis**

Criteria	Retrospective TIA + Window Analysis	Window Analysis + But-For Analysis
Type of Method	Dynamic, retrospective, logic-based	Forensic, retrospective, causal-deterministic
Core Principle	Insert each delay event into the update schedule of that window and recompute CPM	Remove (collapse) delay events in each window to test the "but-for" scenario
Primary Data Requirement	Baseline + contemporaneous monthly updates + as-built data	Baseline + full as-built logic + validated event chronology
What It Measures	Actual time impact of each delay event as it occurred in real time	Hypothetical improvement in completion date if the event had not occurred
Critical Path Tracking	Strong – recalculated per window	Strong – derived from actual as-built logic
Float & Concurrency Handling	Excellent – CPM re-runs show float absorption & overlapping delays	Very strong – concurrency revealed by but-for removal overlaps
Nature of Logic	Forward-looking per window (simulating the event at time of occurrence)	Backward-looking per window (removing delay effects to see true driver)
Complexity Level	High – requires multiple CPM simulations	Very high – requires careful logic reconstruction and removal tests
Dispute / Arbitration Strength	Very strong, widely accepted under SCL & AACE	Extremely strong, often preferred in expert forensic testimony
Best Used When	Monthly updates exist; need to simulate evolving critical path	Highly detailed as-built data exists; need strong causal proof
Limitation	Requires accurate monthly updates	Very data-intensive + risk of artificial logic changes

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