CHAPTER 19

Assessing the Delay Analysis in Multi-storey Residential Project using Time Motion Study

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ABSTRACT

Delays are a common challenge in multi-storey residential construction projects, often leading to increased costs, extended timelines, and inefficiencies in resource utilization. This study aims to assess and analyse such delays using a Time Motion Study, with a focus on real-time tracking of construction activities. By identifying specific delays during project execution, comparing them with industry standards, and proposing mitigation strategies, the research offers practical insights into improving construction efficiency. To achieve this, the study employs the Continuous Timing Method, a real-time observation technique that records the start and end times of various activities without interruption. This method provides a precise and detailed account of productive work, idle time, and delays, offering a clear picture of on-site operations. The collected data is then analysed using the Method Productivity Delay Model (MPDM), which categorizes delays into key areas such as labor inefficiencies, equipment downtime, material shortages, and procedural bottlenecks. By integrating real-time observations with historical project performance trends, this research identifies the root causes of delays and their impact on overall productivity. The study goes a step further by offering targeted recommendations to mitigate these delays, ensuring better workflow management and timely project completion. The findings of this research can be valuable for project managers, contractors, and construction professionals seeking to enhance productivity, reduce inefficiencies, and optimize resource allocation. Ultimately, this study contributes to the broader goal of improving project execution strategies in the construction industry.

Keywords: Delay analysis; Time motion study; Continuous timing method; MPDM; Productivity delays.

1.0 Introduction

1.1 Background

Construction delays affect cost efficiency, project scheduling, and overall productivity. Various factors such as labor inefficiencies, material shortages, equipment breakdowns, and regulatory bottlenecks contribute to these delays.

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The Time-Motion Study (TMS) provides a structured approach to identifying and mitigating inefficiencies. To ensure precise data collection, this study employs the Continuous Timing Method, an observational technique that records activity durations without any interruptions. Borchert & Zellmer-Bruhn, 2010 assert that "work sampling is a reliable predictor of labor productivity, showing a close correlation between on-site observations and unit-rate productivity." Similarly**,** Liou & John, 1986 demonstrate that "work sampling can reveal patterns of idle time, waiting periods, and other inefficiencies across multiple tasks or trades." By capturing the exact time spent on each task, this method helps in identifying inefficiencies, tracking idle periods, and assessing overall productivity levels on-site. Once the data is gathered, it is analysed using the Method Productivity Delay Model (MPDM) — a framework that classifies delays into key categories such as labor inefficiencies, equipment downtime, material shortages, and procedural bottlenecks. By integrating real-time data with advanced analytical methods, this research aims to provide practical, data-driven insights that can enhance project performance, streamline workflows, and ensure timely project completion.

1.2 Objectives

- Identify the causes of delays in a multi-storey residential project, located in Pune.
- Compare observed delays with industry benchmarks and standards.
- Propose strategic solutions to enhance project efficiency.

1.3 Problem definition

Traditional delay analysis methods rely on historical data, making it difficult to implement real-time solutions. This study applies a data-driven approach using real-time tracking of construction activities and productivity analysis. Traditional methods of delay analysis often rely on historical data or subjective assessments, making it difficult to capture real-time inefficiencies and proactively implement corrective actions. This results in reactive problem-solving rather than preventive measures, further exacerbating project delays. To bridge this gap, this study employs Time Motion Study and Continuous Timing Method to record real-time data on construction activities and identify inefficiencies as they happen. The Method Productivity Delay Model (MPDM) will be used to systematically categorize and analyze these delays, providing insights into their root causes and impact on overall productivity.

1.4 Methodology overview

A case study approach was used, applying the Continuous Timing Method to observe and record construction cycles. In order to identify, assess, and minimize delays in multi-story residential construction projects, this study uses a data-driven methodology. With names removed for confidentiality, the study focuses on XYZ, a multi-story residential development in LMN Nagar in Pune, built by ABC Builders. For close examination, the concreting activity was chosen. A Time Motion Study was used to observe work duration in real time, and a Continuous Timing Method was used to continuously track activity start and end times, recording delays and

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idle times. Procedure issues, equipment failure, labor inefficiencies, material unavailability, and external factors were the categories into which delays were divided for data analysis using the Method Productivity Delay Model (MPDM). Actual cycle times were compared to industry-standard benchmarks to determine productivity loss, and production delay sampling tables were used to spot trends. In order to determine acceptable productivity levels and determine critical delays through assessing variability limits, the recorded data was then compared with industry standards. Finally, mitigation techniques were suggested to improve material procurement procedures, equipment management, and workflow optimization. These strategies seek to boost productivity, enhance scheduling, and cut down on delays. The study offers useful insights to increase efficiency in multi-story residential construction projects by utilizing MPDM.

2.0 Literature Review

By following the PRISMA framework (Identification, Screening, Eligibility, Inclusion), the study ensured a structured and rigorous approach to selecting literature. The 17 included papers form a strong foundation for analyzing how MPDM and Time-Motion Studies can effectively address construction delays.

2.1 Time-motion studies in construction

In the construction industry, time and motion studies have long been recognized as essential tools for locating inefficiencies and boosting output. These studies assist in identifying ineffective times and possible areas for optimization by closely observing activity durations and workflows. Balar (2018) asserts in "Effective Time and Motion Study on Construction Project: A Case Study of Surat City" that these kinds of analyses can cut down on waste, optimize processes, and enhance project results in the end. The importance of examining labor productivity in residential construction was also emphasized by Chambrelin (2021) in "Application of Time and Motion Study for Brickwork Activity in Residential Building." The study demonstrates how statistical analysis and structured observation can greatly increase productivity. Building on these foundational studies, accurate measurement is essential to identify delays, assess resource distribution, and prioritize tasks that need immediate attention.

2.2 Work sampling and relevance to MPDM

Work sampling predicts labor productivity and helps in categorizing delays into labor inefficiencies, equipment downtime, material shortages, and procedural delays.

2.3 Factors affecting productivity and delays

- ***Material shortages:*** Delays in procurement and supply chain inefficiencies.
- ***Labor inefficiencies:*** Workforce shortages and lack of coordination.
- ***Equipment downtime:*** Mechanical failures and poor maintenance.
- ***Management and workflow:*** Miscommunication and procedural bottlenecks.

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2.4 Research gap

The Method Productivity Delay Model (MPDM) is effective for identifying and minimizing construction delays, but focusing on a single concreting activity reveals specific gaps. These include limited studies in the Indian context considering local labor practices and supply chains.

Key gaps are: Limited Task-Specific Analyses: Broader studies dilute insights; focusing on concreting can reveal overlooked inefficiencies. Overlooked Micro-Delays: Brief, repeated disruptions are often missed. Real-time tracking can capture these better. Inconsistent Data Quality: Multi-trade projects lead to fragmented data. Focusing on concreting ensures accuracy. Lack of Real-Time Observation: Many MPDM studies lack continuous monitoring, reducing data precision. Shallow Root Cause Analysis: General categories often miss specific sub-causes like truck scheduling vs. crew timing. Scalability Issues: Multi-task findings may not transfer well; single-activity benchmarks are more adaptable. Addressing these gaps can strengthen MPDM's application for managing delays in Indian construction projects.

3.0 Research Methodology

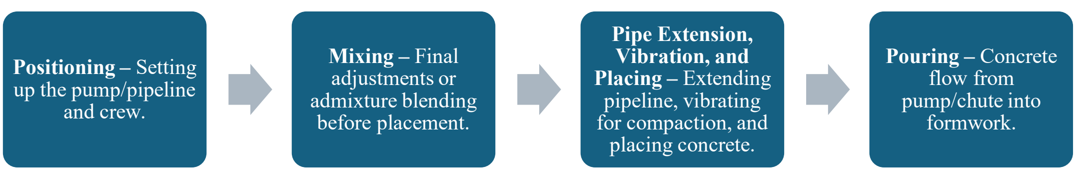
A common approach for carrying out Time-Motion Studies (TMS) on dynamic construction sites is observation. Despite being qualitative, it can provide quantifiable insights when methodically combined with quantitative analysis. Real-time insights into task completion, time spent, and inefficiencies can be obtained by classifying delays and recording precise time intervals using observational data and models such as the Method Productivity Delay Model (MPDM). By capturing start and stop times in real time, the Continuous Timing Method facilitates even more accurate tracking of productive versus non-productive time. In order to precisely identify delays in concreting activities, durations and idle periods were recorded using the continuous timing method.

3.1 Defining a concreting cycle

Cycle Determination by RMC Arrival: Each Ready-Mix Concrete (RMC) batch (5-6 m^3) was treated as one cycle, starting from the truck/pump setup to the finishing step.

Total Number of Cycles: Over 3 days, 42 cycles (~14/day) were recorded.

3.2 Activities within each cycle



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3.2.1 Continuous timing method, data recording and organization

The data collection process involved uninterrupted observation, where start and stop times were logged in real time to ensure accuracy. Time log sheets or digital timers, such as stopwatches, were used to monitor each phase of the concreting activity systematically. Additionally, any idle periods caused by waiting, equipment malfunctions, or realignments were carefully recorded, allowing for a comprehensive capture of real-time delays. The duration of each sub-activity was calculated by subtracting the start time from the end time. The overall cycle duration included the total of all sub-activities combined with idle time. Daily summaries were compiled to track productivity patterns, and all data were consolidated into a master spreadsheet for further analysis.

3.3 Identifying and categorizing delays along with outcome of continuous timing

Delays or idle time have been documented as a result of issues with management, labor, materials, equipment, or the environment. The Method Productivity Delay Model (MPDM) was used to group these delays into the following categories: management, environment, materials, labor, and equipment. The most important bottlenecks influencing productivity were then determined by quantifying the delays over 42 cycles. Precise timelines for each of the 42 cycles were provided by the creation of detailed cycle profiles. By using these profiles as the basis for MPDM analysis, inefficiencies in the concreting process were found. Both recurring and one-time delays were identified by comparing the cycles, providing useful information for resolving productivity problems.

3.4 Observer roles and data accuracy

Observer roles were clearly defined, with two observers tracking RMC truck activities and two monitoring labor tasks, with periodic role rotation to maintain objectivity. Time measurement methods were improved using stopwatches, structured log sheets, and cross-verification for accuracy. Additionally, increasing the number of observations to 42 cycles, rotating observers, and rechecking entries helped reduce measurement errors and minimize inconsistencies.

4.0 Data Analysis and Findings

4.1 Delay categorization

- Labor Delays (37%): Workforce shortages, inefficient scheduling.
- Equipment Delays (20%): Pump failures, tower crane inefficiencies.
- Material Delays (14%): Late deliveries, inventory mismanagement.
- Environmental Delays (15%): Weather and regulatory issues.
- Management Delays (14%): Miscommunication and slow decision-making.

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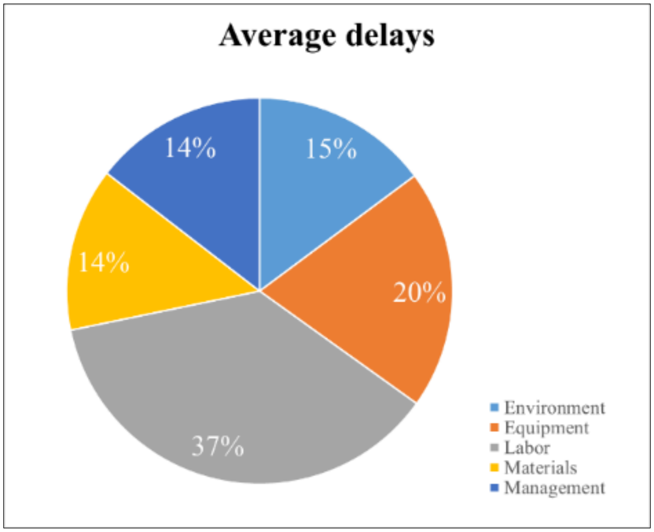
Figure 1: Average Delays in Pie Chart



4.2 MPDM processing

Table 1: MPDM Processing

	Total Production Time	Number of Cycles	Mean Cycle Time	Variance
(A) Non-Delay Production Cycles	33391	42	795	105
(B) Overall Production Cycles	58451	42	1392	229

Source: Compiled by authors

4.3 Delay information processing

Table 2: Delay Information Processing

	Delay				
	Environment	Equipment	Labor	Materials	Management
(C) Occurrences	9	8	40	13	11
(D) Total Added Time	1472	1836	18167	1753	1833
(E) Probability of Occurrence	0.2143	0.1905	0.9524	0.3095	0.2619
(F) Relative Severity	0.1175	0.1649	0.3263	0.0968	0.1197
(G) Expected % Delay Time per Production Cycle	2.5184	3.1412	31.0739	2.9977	3.1345

Source: Compiled by authors

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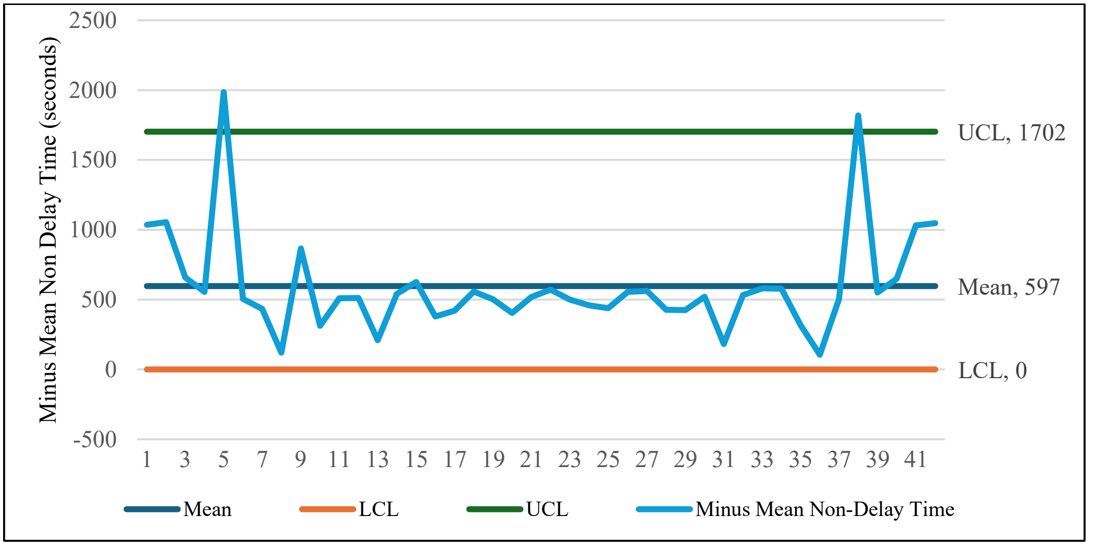
4.4 Productivity analysis

- Ideal Productivity: 4.5283 units/hr
- Actual Productivity: 2.5872 units/hr (Productivity loss: ~43%)
- Cycle Variability: 6.911, Higher fluctuations indicate process inefficiencies
- Prodcutiviy Eficiency: 57.13%

4.5 Statistical Insights

The control charts revealed deviations beyond acceptable limits, indicating irregular delays in certain cycles.

Figure 2: Control Chart



The normal distribution analysis confirmed that most delays fell within a predictable range; however, outliers significantly affected overall efficiency. This control chart visualizes the variation in Minus Mean Non-Delay Time (in seconds) across different cycles to assess the process stability and detect anomalies. A line showing actual cycle time variations – highlighting fluctuations over different cycles. Most the cycles remained within control limits, fluctuating between 0 and 1000 seconds, indicating that delays were within an acceptable range. This suggests a stable process with potential for improvement. However, two major outliers — Cycles 5 and 38 — exceeded the Upper Control Limit (UCL), indicating significant delays in these specific instances. Additionally, while several cycles hovered close to the mean line of 597 seconds, performing as expected, a few cycles approached the Lower Control Limit (LCL) of 0 seconds, suggesting minimal or no delays and indicating an optimized workflow.

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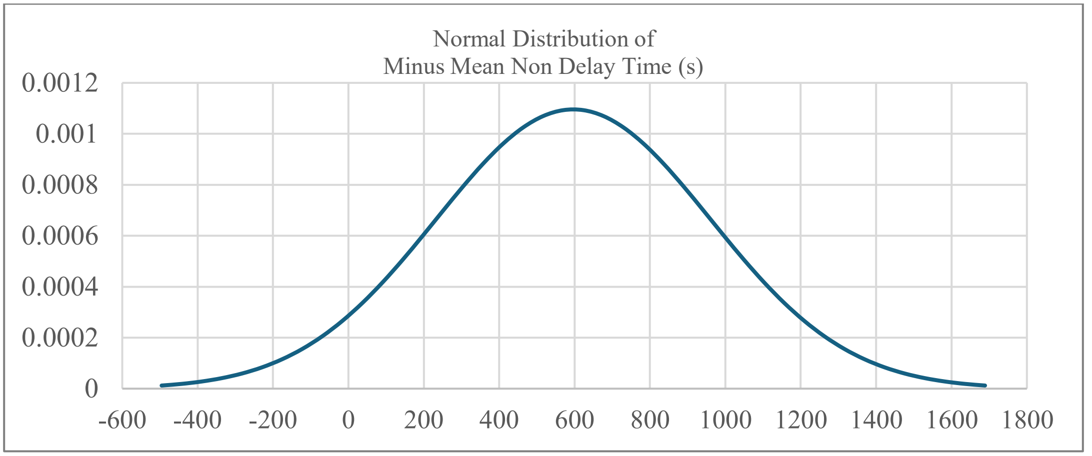
Figure 3: Normal Distribution Curve



Mean	597
std dev	364.0757043
99.7% Low	-495.5366368
99.7% High	1688.917589
Steps	41
Gap	53.27937136

The normal distribution curve illustrates the spread of minus mean non-delay time (s) around the mean value of 597 seconds. The bell-shaped pattern suggests that most observations cluster around the mean, with a moderate spread indicated by a standard deviation of 364.08 seconds. This implies that while most values are close to the average, some show notable deviations. The 99.7% confidence range, spanning from -495.54 seconds to 1688.92 seconds, captures almost all data points, highlighting occasional extreme variations. The curve's symmetry shows that deviations on both lower and higher ends are balanced, ensuring a fair distribution. This visualization helps assess the reliability of measured times, predict future delays, establish acceptable time variation thresholds, and conduct risk assessments for the concreting process.

5.0 Conclusion, Limitations and Recommendations

Conclusion: The study used statistical tools like pie charts, bar charts, control charts, and normal distribution graphs to analyze delays in the Nayati Evoque residential project. Material shortages (14%) and labor inefficiencies (37%) were the primary delay factors. External issues like weather and regulatory approvals added 15% more delays. Concrete operations alone caused 25% of delays due to equipment issues and inconsistent cycles. Control

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charts revealed significant variations, while the normal distribution showed an average delay of 597 seconds. Overall, better planning, real-time tracking, and advanced technologies like AI could reduce delays and enhance efficiency.

Limitations: The study's scope is limited to a single project, reducing the generalizability of its findings. Uncontrollable factors like strikes or weather and reliance on manual data collection can introduce errors. Short observation periods limit long-term insights, and the study relies heavily on industry benchmarks that may not apply everywhere. Despite these limitations, the study offers a foundation for future research with more extensive data and advanced technologies.

Recommendations: Future research should include multiple projects for broader insights. Automated -data collection using AI, sensors, and IoT can reduce human errors. Advanced statistical tools like machine learning can improve analysis, while global standards can enhance relevance. Including stakeholder feedback can provide a deeper understanding of on-site challenges.

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