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Overcoming the Practical Gap in Planning and Execution Phases of Residential Building Construction Using Cost-Effective AI Tools in Rural Areas

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Abstract

This research paper explores the challenges faced during the planning and execution phases of residential building construction in rural area, with a focus on bridging the gap between theoretical knowledge and practical implementation. The study emphasizes the use of cost-effective Artificial Intelligence (AI) tools to streamline construction processes, reduce delays, and optimize costs. A residential building project from a rural area was selected for analysis, covering aspects such as site clearance, planning, estimation, scheduling, and execution. The study compares theoretical estimates with actual costs, identifies delays and their causes, and evaluates the effectiveness of AI tools in mitigating these challenges. The findings highlight the potential of AI in improving construction efficiency, reducing material wastage, and enhancing decision-making in resource-constrained rural environments. This research aims to provide actionable insights for civil engineers, contractors, and policymakers to adopt AI-driven solutions for sustainable and cost-effective construction practices in rural areas.

Keywords: *Planning-Execution Gap, Artificial Intelligence (AI) tools, sustainable and cost-effective construction practices.*

1. Introduction

1.1. Background

Residential construction projects often struggle to align theoretical designs with on-site execution due to factors such as labor shortages, material procurement delays, and unforeseen site conditions. This gap is particularly pronounced in rural areas, where access to advanced technologies and skilled labor is limited. This paper investigates how cost-effective AI tools can bridge this gap, ensuring efficient and sustainable construction practices.

1.2. Aim

The primary aim of this research is to identify the practical challenges in residential building construction in rural areas and propose AI-driven solutions to overcome these challenges. The study also aims to evaluate the effectiveness of AI tools in reducing delays, optimizing costs, and improving overall project efficiency.

1.3. Objectives

- To analyse the gap between theoretical planning and practical execution in rural construction projects.
- To evaluate the role of AI tools in optimizing construction processes, including planning, scheduling, and material management.
- To propose cost-effective AI solutions

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tailored for rural construction projects.
- To assess the impact of AI tools on reducing material wastage and improving decision-making on-site.

2. Methodology

2.1. Data Collection

The study involved the analysis of a residential building project in a rural area, focusing on the following aspects:

- Planning and design using AutoCAD.
- Cost estimation using MS Excel.
- Scheduling and tracking using MS Project. [1-5]

2.2. Estimation and Costing

The cost estimation for the residential building was conducted using the plinth area method. The total cost was calculated as follows:

- Labour + Material Cost
  Total Cost = Total Plinth Area × Rate per Square Feet
  = 1200 × 1450 = ₹17,40,000
- Labour Cost Only
  Total Cost = Total Plinth Area × Rate per Square Feet
  = 1200 × 165 = ₹1,98,000

2.3. Onsite Observations

A comparative analysis was conducted between theoretical estimates and actual execution, focusing on the following parameters:

- Time taken for each construction activity and delay
- Cost variations due to material price fluctuations.
- Changes made to the original plan during execution.

2.4. Cost-Effective AI Tools and Applications

2.4.1. Planning Phase

2.4.1.1. Generative Design with Free CAD

- Open-source software for creating optimized building layouts.
- Reduces design errors by auto-correcting measurements (e.g., converting cubic meters to feet).

2.4.1.2. AI-Powered Estimation Tools

Mobile apps like Estimate Now uses historical data to predict material costs with 90% accuracy.

2.4.2. Execution Phase

2.4.2.1. Computer Vision via Smartphone Cameras

Apps like *Open CV* detect structural defects (e.g., cracks in concrete) using image recognition.

2.4.2.2. IoT-Based Material Tracking

Low-cost sensors monitor cement and sand usage, alerting teams about shortages via SMS.

2.4.3. Project Management

2.4.3.1. Trello with AI Plugins

Free task management tool with predictive timelines to adjust schedules dynamically.

2.4.3.2. AI Weather Forecasting

Free apps like *AccuWeather* provide hyperlocal forecasts to reschedule outdoor tasks.

2.4.4. Cost-Effectiveness

Low-Tech Adaptations Open-source tools (e.g., Tensor Flow Lite) and repurposed drones kept costs under ₹50,000.

3. Results and Discussion

Table 1 shows the comparative analysis between theoretical approach, practical execution and AI Driven solutions.

4. Key Findings

- The planned duration for construction was 4 months, but the actual duration was 6 months and 16 days. AI tools may reduce delays by 20%.
- The estimated cost of construction was ₹11, 26,560, while the actual cost was ₹13, 00,000. AI tools will help to reduce the cost overruns by 15%.
- Changes in scheduling were primarily due to external factors. AI tools will provide real-time adjustments to the schedule.
- Material costs fluctuated due to supply chain disruptions. AI tools will have optimized material procurement and reduced wastage.
- AI tools will improve decision-making on-site by providing real-time data and predictive analytics

5. Challenges

- Skill Gaps: Workers required basic training to interpret AI outputs.
- Infrastructure Limitations: Intermittent power

and internet in rural areas necessitated offline-capable tools. [6-9]

6. Policy Implications

- Subsidized Toolkits: Governments could fund AI starter kits for small contractors.
- Training Programs: Partnerships with NGOs to upskill rural labour in digital tools.
- Table 1 shows Comparative Analysis

Table 1 **Comparative Analysis**

S. No	Parameter	Theoretical Approach	Practical Execution	AI-Driven Solution
1	Layout Marking	Plumb Bob, Lime, Sand, Rope	Plumb Bob, Lime, Sand, Rope	AI-assisted layout marking
2	Excavation	Mechanically / Manually	Manually	AI-optimized excavation
3	Cost Estimation	Plinth Area Method	Plinth Area Method	AI-based cost prediction
4	Dewatering	Mechanically / Manually	Manually	AI-monitored dewatering
5	Concrete Mixing	M25/M20 (1:8:12)	Thumb Rule	AI-controlled mixing
6	Scheduling	MS Project	Manual Tracking	AI-powered scheduling
7	Material Management	Manual Tracking	Manual Tracking	AI-based material tracking

Conclusion

Cost-effective AI tools significantly narrow the gap between theoretical planning and practical execution in residential construction. By adopting affordable solutions like open-source design software, mobile-based monitoring apps, and IoT sensors, small-scale contractors can enhance accuracy, reduce waste, and improve project outcomes. Future efforts should prioritize AI literacy programs and develop offline-capable tools to address rural infrastructure limitations.

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