

Assignment#3

Assignment Report: Benefits of Machine Learning in Construction Management

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Abstract

Overruns, delays, safety incidents, and poor information flow are commonly encountered in construction projects. The latest evidence suggests that machine learning (ML) can help project teams predict risks, schedule projects, monitor project progress, and support near real-time safety decisions (OUCI). Nevertheless, many contractors – particularly in developing nations – still do not have an explicit plan for implementing ML in daily construction management.

This study intends to pinpoint and structure the main advantages of ML in construction management and to conclude a conceptual framework where project managers could use to plan the actual projects implementing ML. The research will add to the literature that already exists on ML in construction productivity, safety, schedule, and progress monitoring and will broaden it with more recent studies (OUCI). This research will adopt a mixed-method design: (1) a systematic literature review, and (2) qualitative interviews with construction and data experts. By integrating these two components we will develop and validate a framework that connects ML use cases with project phases, data needed, benefits, and challenges in projects.

The expected results are:

1. an explicit outline for the greatest benefit that ML in construction management provides
2. a structured set of actions that can guide companies toward adoption of ML, as well as
3. recommendations for future work around ML in construction management—particularly in the Middle East.

Keywords: Construction management, machine learning, artificial intelligence, project scheduling, safety management, productivity, framework.

1. Introduction

1.1 Background of the Study

Construction is always hit with low productivity, frequent delays, and cost overruns. A lot of projects still rely on manual spreadsheets, 2D drawings — and on the technical experience of the engineers who built them. Meanwhile, modern construction sites produce lots of data in massive quantities through BIM models, planning software, sensors, drones, and project management systems (OUCI).

Machine learning (ML), an area of artificial intelligence that is used to extract patterns from the data, has begun to become significant in the construction engineering and construction management field. ML supports cost predictions, schedule predictions, safety risk detection, quality control, resource efficiency models, among others (ScienceDirect). Furthermore, ML can work in conjunction with BIM and digital twins to automate decision making at the time of deciding on a project and optimize project performance at every phase of a project lifecycle (MDPI).

But in spite of this promise, there are now a growing number of construction firms that do not know how to apply ML in actual construction practice. They still aren't sure what use cases to start with, what data needs to be collected, what algorithms to choose, and — worst of all — how to handle the change inside the organization. Research, reviews, and bibliometric studies also indicate that the majority of existing work does not focus on implementation frameworks for project managers that can be followed in reality, except around technical models (e.g., accuracy or algorithms) (ScienceDirect).

This research investigates “The Benefits of Machine Learning in Construction Management” to convert the scattered researches into a clear and meaningful framework to drive a real project.

1.2 Problem Statement

New investigations demonstrate ML has significant advantages for construction management:

- Predicting cost and time performance (OUCI).
- Modelling labour and equipment productivity at the level of activity (OUCI).
- Supporting safety management by predicting high-risk situations and analysing images or videos from site activities (MDPI).
- Helping to ensure a more precise, data-driven scheduling through ML's integration with BIM (MDPI).
- Automating progress monitoring for prefabricated or modular projects with computer vision (PubMed).

But these studies are fragmented in large part. A lot of them only deal with one specific task, whether accident prediction or schedule generation, or they test on small datasets in one country or just a specific kind of project (ScienceDirect). There is no universally accepted framework that can describe and integrate all these advantages:

- What ML applications would be most useful for different construction management functions.
- What data and digital infrastructure do you require?
- A step-by-step framework for project managers and engineers on how to implement ML across their organizations.
- How these benefits can be realised for countries that are still in transition towards digital maturity as are the Middle East.

For this reason, many project managers are trained on the importance of ML, yet lack idea of where to begin. This delays adoption and robs them of their potential.

Problem statement: Although the benefits of using machine learning in construction management with regards to forecasting, productivity, safety, monitoring progress, etc. have been reported in research, no unified, applied and practice-oriented framework is available to assist construction project managers to spot, understand their high value ML use cases, their data and implementation requirements, and to put in place steps to enable project execution in practice and the adoption of ML technologies in construction projects particularly in developing countries.

1.3 Research Objectives.

Broad objective:

- Aim To construct a usable framework that provides a compact description of the advantages of machine learning in construction management and guidance to implement ML use cases in real construction projects.

Specific objectives.

1. To review and draw out of existing investigation on the uses of machine learning in construction management (cost, time, safety, quality, productivity and progress monitoring) (ScienceDirect).
2. To categorize advantages of ML by project lifecycle stages (planning, execution, monitoring and control) and primary management activities (MDPI).
3. To present key challenges and success factors in the realization of ML in construction companies such as data availability, digital tools, skills, organizational challenges (MDPI).

4. To suggest and validate a conceptual framework that ties ML use cases, inputs needed, expected benefits, and implementation steps for construction management practice.

1.4 Research Scope.

This study focuses on:

- Domain: Construction management (not structural design or material science).
- Types of projects: Mostly commercial, residential building and infrastructure projects. Examples may be pulled from the Middle East if possible.
- Technology: Machine learning methods (both traditional supervised learning technique and deep learning) for planning, scheduling, safety, productivity and progress monitoring.
- Level of analysis: Project and company level (not national or government policy).
- Method: Conceptual and empirical (literature review and expert interviews). This research will not create new ML algorithms. Instead, it will organize and interpret existing work into a usable framework.

1.5 Significance of the Study

This study has several important contributions:

- It organizes scattered information about ML in construction into a clear map of use cases and benefits
- It also offers real-world advice for project managers, planners and safety engineers who want to embrace ML but lack a roadmap.
- It can strengthen digital transformation efforts undertaken by construction companies in areas where digital tools and data culture are just emerging (ijsrce.com).
- It identifies gaps in the literature and also points out where they have work to do: understudied applications of ML and evaluation into actual project impact.

2. Literature reviewing:

In assignment 1 - literature review six major studies were selected for research on AI on building management (cost, schedule monitoring, safety and progress monitoring). This chapter concludes and builds on the review with newer work with reviews and critical discussion of ML in construction productivity, safety, and management.

2.1 Machine Learning in Construction Engineering and Management:

A general overview. Pan and Zhang (2021) conducted a broad scientometric and qualitative survey on AI in construction engineering and management using 4,473 paper-reviews from 1997 to 2020. They demonstrate that AI and ML is in extensive use for modelling, prediction and optimization, among others, for scheduling, cost estimates, resource planning and safety (OUCI). In the review they document significant advantages: the accuracy of prediction is enhanced, routine decisions can be automated and complex and high-dimensional data can be properly addressed compared to traditional techniques.

A hybrid bibliometric study of machine learning used in making construction methods (2015–2022) organizes the use cases of ML in concrete technology, retaining walls, pavements, tunnelling and construction management (ScienceDirect). It also illustrates the tendency of construction management use cases to move more towards risk prediction, site monitoring, scheduling, and decision support.

Datta et al. (2024) offer a scoping review of AI and ML applications in the construction project lifecycle, from planning with the construction project itself to operation, for example. They note that ML predicts the performance of projects, schedules, safety risks, resource allocation and scheduling, and is a method for making decisions under different activities but they add that a large part studies have still been research-driven and not yet fully tested in actual works.

Collectively these reviews confirm the role of ML in new generation construction management practices, although such evidence rests on numerous separate case studies.

2.2 ML -Cost, Time and Productivity Management:

Several studies analyze the time and cost savings of ML applied in construction management. AI in construction management have recently been reviewed and ML models can help with cost estimation, duration prediction and change-order impacts by taking feedback from historical project data (ijsrce.com). Datta et al. (2024), ML-based

cost and prediction of time often outperforms standard regression models (especially where design, contract, and site variables are used) on large datasets.

Lim, Yi, & Wang (2024) examine ML tools for construction productivity at the activity scale, in terms of labor and equipment productivity. They argue that ML is beneficial model on effects of weather, crew size, machine type and work sequence for prediction of efficiency and planners will be able to optimise scheduling and resource allocation according to the OUCI. Also important is that on successful model, they stress the importance of quality labeled data and suitable feature selection for good performance.

Al-Sinan et al. (2024) present a machine-learning + BIM-based schedule generation model based blueprint for scheduling generation in this paper. Their strategy employs machine-learning approaches to develop existing schedules and project features via ML where ML learn from past schedules and attributes of previous work, automatically predicts new schedule within BIM (MDPI). Their work will have tangible wins like a more rapid planning time increase, scheduling, dynamic rescheduling and better integration of design models, time planning.

It appears from these studies that ML can cut down planning time, enhance forecast accuracy, and facilitate decisions around cost and time proactively; factors that are fundamental in construction management.

2.3 ML in Safety and Risk Management:

Safety is one of the most active sectors for ML in construction. As per latest systematic review of literature for construction AI, some of ML and deep learning models were applied for prediction of incident, awareness of hazard and detection of unsafe behavior, as using based upon historical accident data, site pictures, video and sensor signals (MDPI).

Other construction review on ML also highlights safety applications as a significant research theme: it models predict and uses predictive models to predict the possibility of accidents from the characteristics of the project, the weather conditions or the behavioral pattern of the worker, and using computer vision the machine identifies missing PPE or unsafe positions for heavy machinery (ScienceDirect).

These are excellent studies for the safety management of:

- Early warning of high-risk operations that enable the supervisors to take the necessary measures before an accident is realized.
- Automated checking of safety compliance (e.g., helmets, vests, harness) through cameras and deep learning.
- Better insight into patterns and underlying causes of accidents.

However, they also identify problems such as data privacy (for worker images), model bias and poor compatibility with existing safety systems, which this study will incorporate into the framework as well.

2.4 ML for Progress Monitoring, Quality, and Site Management

Deep learning is also used to monitor progress and site management. Deep-learning models and software for monitoring the progress on site images of Prefabricated Prefinished Volumetric Construction (PPVC) have been used to automate monitoring of module installation and comparing actual progress with planned schedules (PubMed). A system with an automated method to record completed quantities (from which, a system can determine deviations) or output dashboards for managers.

Wider reviews of ML in construction further illustrate that computer-vision-based monitoring, for instance, continues to be among the most robust research areas - with direct correlation to monitoring quality controls, logistics, and equipment tracking (ScienceDirect). The drone images, fixed cameras, and ML models can help companies create an almost real-time digital picture of the site. That improves coordination, speeds inspections, and avoids rework.

These studies illustrate that ML can help narrow the gap between plan and reality by being able to keep tabs on real-time progress and quality on site.

2.5 Synthesis of Benefits

Based on the literature that we reviewed, four types of benefits are primarily derived from ML in the areas of construction management:

1. Improved planning and predicting.
 - More accurate cost and schedule forecasts (OUCI).
 - Data-based models of labour and equipment productivity (OUCI).
2. Better monitoring and control.
 - Images/video-based automated progress tracking (PubMed).
 - Early identification of deviations from schedule and budget (MDPI).
3. Improved safety management. MDPI:
 - Prediction of high-risk situations and near misses.
 - System for identifying unsafe acts and lack of PPE with the aid of computer vision.
4. Decision support and optimization, both at work.

- ML models optimize resources, equipment usage, and construction methods, and assist managers in making an informed decision between various possible scenarios (ScienceDirect).

2.6 Research Gaps

However, despite these benefits, some gaps exist:

- Many ML solutions are technical prototypes, and lack clear implementation guidelines for contractors (how to start, what data to collect, who should be involved) (OUCI).
- More concretely, work that brings together various functions (cost, schedule, safety, quality) into an integrated system for construction management is scarce.
- Much research is based in developed countries and provides limited guidance to less digitally mature areas, including some parts of the Middle East (ijsrce.com).
- Ethical, organisational and data governance issues (such as worker privacy, change management) are mentioned but not all integrated into the construction-focused frameworks (MDPI).

This study therefore seeks to address these identified gaps by constructing an integrated, practice-oriented framework rooted on both advantages and practical implementation of ML in construction management.

3. Research Methodology

This study is exploratory: a mixed-method design is employed. It stages a literature review supplemented by expert interviews, and then utilizes both of these to develop and test a framework. This logic follows the structured work in the framework-development for AI and construction management (OUCI).

3.1 Research Design

The research will be accomplished in three main phases:

1. Phase 1 – Extended Systematic Literature Review.
2. Phase 2 – Qualitative Expert Study (Interviews / Focus Groups).
3. Phase 3 – Framework Development and Validation.

The three phases are congruent with research objectives (a) to investigate the existing benefit of ML to present research question or problems and (b) to support the development of a practical implementation framework for ML.

3.2 Phase 1: Broader systemic study of the literature

Purpose:

To continue an examination of the literature on Assessment 1 and to summarize data and information related to the research questions in relation to the applications of ML in construction management practice and to add more recently published works.

Data sources:

- Databases such as Scopus, Web of Science, IEEE Xplore, ScienceDirect, MDPI and Google Scholar.
- Keywords search: (Different combinations): “Machine learning”, “Construction management”, “cost prediction”, “Schedule forecasting”, “Safety”, “Productivity”, “Progress monitoring”, “BIM”, “digital twin” (OUCI).

Inclusion criteria:

- Papers in peer-reviewed journal or conference.
- Focus mainly on ML or AI methods of construction management or in a similar kind of task.
- Mostly published post-2015 with a focus on contemporary ML (ScienceDirect).

Outputs:

- A paper-specific literature matrix summarizing problem, data, ML method, benefits and limitations.
- Chapter 2 An updated literature review chapter that outlines and compares all findings.

3.3 Phase 2: Qualitative expert study

Purpose:

To gather pragmatic perspectives on practical perspectives on advantages, barriers and facilitators of implementation of ML in construction management.

Participants:

- Around 10–15 experts like the following:
 - Management and planners of construction project.
 - Site Engineers and safety officers.
 - BIM / the digital transformation manager.
 - Data scientists/ML engineers using construction data.

Sampling:

- Purposive sampling to select individuals with a hands-on experience with digital tools, or data-driven management.
- When you can, pull in experts in the Middle East (Iraq, and its neighboring countries) to localize this region, when at least possible.

Data collection method:

- Semi-structured interviews, online or offline.
- Interview topics:
 - Presence of data and digital tools in project management.
 - Knowledge and application of ML tools.
 - Benefits perceived to be beneficial (time, cost, safety, quality).
 - Obstacles: data quality, skills, culture, cost, trust.
 - Recommendations for a realistic ML Adoption roadmap.

Data analysis:

- Interviews will be audio recorded (only if permission is obtained), then transcribed.
- Analysis comments will be organized into themes based on a thematic analysis: “benefits”, “challenges”, “data issues”, “organizational factors”, “priority use cases”.

These findings will validate and narrow the advantages and limitations of the literature and bring to life the real world context.

3.4 The third phase is the development and validation of a framework.

Framework development and construction:

- Combine the results from Phase 1 and Phase 2 studies to come up with a Machine Learning in Construction Management Implementation Framework.
- It may include:
 - Use-case categories (Cost / Time Forecasting, Productivity Modeling, Safety Monitoring, Progress Tracking)
 - Data tool required (BIM, Scheduling Tools, Sensors, Cameras).

- Benefits anticipated or expected (e.g. reduced delays, fewer accidents, increased productivity).
- Steps to implement e.g verifying data readiness, pilot projects, team training, integration with already existing systems

Validation:

- Expert Review: A draft of the framework will be sent to an identified expert community group for their opinion regarding its clarity, completeness and practicability.
- Optional pilot assessment: The framework will be utilized, to the extent possible, on a hypothetical/sample project. Experts will determine the utility and feasibility of each step.

Evaluation criteria:

- Will the model be simple for non-technical managers to read?
- Does it provide the primary use cases of ML on construction management?
- Is it within realistic limits given common constraints (budget, skills, data)?
- Is it consistent with recent findings from ML-in-construction reviews (OUCI)?

3.5 Ethical Considerations.

Ethical considerations primarily arise in Phase 2 and any applications of project data:

- Informed consent: All participants will be made aware of the objective of the research project and will consent to participate.
- Confidentiality and anonymity: No names of people & companies will appear in the final report. All responses will be de-identified.
- Any project-specific data (documents, schedules, cost or budget etc.) used in the study will be de-identified to suppress sensitive information.
- When it comes to ML use cases involving images or videos of workers, the framework will ensure that both privacy rules and ethical safety research guidelines, as set forth in AI-in-construction-safety literature (MDPI), are respected, a process that will also be shown in the framework.

Ethical guidelines for university and other associated policy will dictate research participation.

3.6 Limitations

There are some drawbacks of the study:

- It will not build new ML algorithms, but will synthesize what has been done, then create a management level model.
- The list of experts that can be interviewed may be limited, so the findings may not reflect all corporations or countries.
- The literature review will primarily rely on English-language publications — thus, potentially overlooking work in other languages (OUCI).
- The framework might be a better fit for medium and large firms, which already have some digital tools, and for tiny, very small contractors, they may face additional problems.

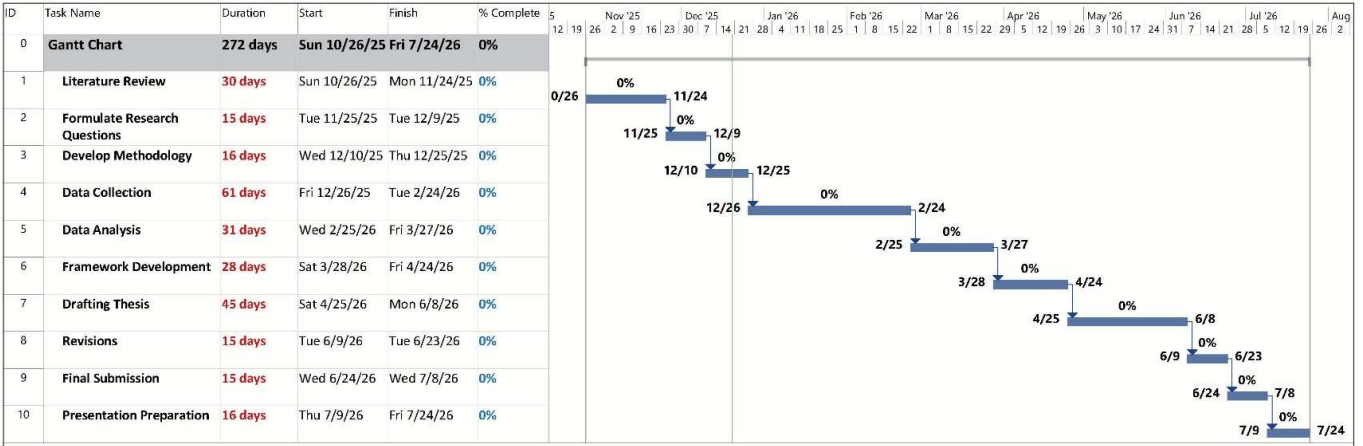
Even at these limitations, the study should yield valuable guidelines to researchers and practitioners.

3.7 Expected Outcomes.

The most expected outcomes are listed below:

1. ML benefits in construction management explainer.
 - A summary of the ML approach is presented (OUCI).
2. Classification of ML use cases by lifecycle and function.
 - A basic map of which ML applications fell into planning, execution, and monitoring/control phases (MDPI).
3. Implementation challenges and success factors.
 - Technical, organizational, and ethical issues, with proposed actions (e.g., quality of data, training of staff, privacy and security of safety-related ML) (MDPI).
4. ML framework for construction management.
 - A guideline for project managers to embark at the beginning on ML adoption journey, choose pilot use cases, and incrementally scale-up.
5. Suggestions for future study.
 - Recommendations for further examination of developing country case studies, and for the application of integrated ML–BIM–IoT solution in construction management.

3.8 Gantt Chart



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