CHAPTER I

INTRODUCTION

1.1 Background

The construction industry is a strategic sector with a significant impact on the economy through its linkages with the building materials industry, logistics, financing, and professional services. From a macroeconomic perspective, Indonesia's economic performance has demonstrated relatively stable growth, with the construction sector recording the highest growth rate compared to several other business sectors. According to Statistics Indonesia (Badan Pusat Statistik/BPS), the year-on-year (y-on-y) growth rate by business sector in the second quarter of 2024 indicated that the construction sector achieved a growth rate of approximately 7.29%. This increase highlights construction as one of the key drivers of economic growth, thereby emphasizing that improvements in timeliness and cost efficiency in construction projects hold substantial strategic value for the national economy.

Source: (BPS, 2024)

Figure 1. 1 Gross Domestic Product (GDP) Growth by Business Sector(y-on-y) 2024

Meskipun Despite its strategic role, the construction industry in Indonesia continues to face persistent challenges related to project delays and cost overruns (Rezki Ian, 2025). A report published by the Directorate General of Construction Development Bina Konstruksi, (2024) under the Ministry of Public Works and Housing (PUPR) in 2024 stated that the rate of project delays in Indonesia remains relatively high, reaching approximately 38%. This condition has the potential to trigger cost escalation during project implementation (Soviana et al., 2024). Furthermore, the analysis conducted by Asril et al., (2025) indicates that these issues are frequently influenced by weak progress monitoring, delays in corrective decision-making, and ineffective control mechanisms when field deviations occur. In many cases, project control practices remain reactive in nature, as corrective actions are implemented only after deviations have become significant, rather than being prevented early through an effective early warning mechanism. This finding suggests that project delays are not merely technical problems occurring in the field, but also reflect weaknesses in data-driven control systems for early detection.

In project control practices, methods such as Earned Value Management (EVM) have been widely utilized to quantitatively measure cost and schedule performance (Talang Rasa et al., 2023) However, the implementation of EVM in practice often remains limited to evaluative or descriptive functions, such as deviation calculations and final cost estimations, and has not yet evolved into an operational system capable of predicting deviations in subsequent periods. In addition, project dashboard implementations across various organizations are predominantly reporting-oriented and are not always supported by a robust data management architecture, resulting in inconsistent integration of data from multiple sources.

On the other hand, research and implementation of Machine Learning (ML) in the construction sector have continued to develop, yet these approaches frequently operate independently as general delay prediction models without incorporating periodic EVM indicators as part of a structured weekly project control dataset (Sahu et al., 2025). Meanwhile, Lean Construction has often been applied as an approach to enhance performance and reduce waste; however, in many implementations, it has not been directly integrated with predictive system outputs as a basis for early warning–driven corrective action recommendations.

This condition is also experienced by PT Royal Project Management, a company operating in the fields of architectural services and property development, with a focus on architectural and structural design for various project scopes. Based on the company's internal evaluation over the past five years, it was recorded that four of the projects undertaken experienced delays in project completion, including the Type-45 housing construction project. The Type-45 housing project was selected for this study because its work cycle is relatively simple, its project duration is shorter, and its cost structure is more controllable compared to high-rise or large-scale projects, thereby enabling more detailed observation of schedule and cost deviations. In addition, Type-45 housing projects represent the most frequently executed project category within the company, resulting in more adequate and representative historical data for the development of a data-driven project control system. This condition further confirms that project control practices remain reactive in nature, as corrective actions are generally implemented only after deviations have occurred.

Table 1. 1 Project Progress Summary by PT Royal Project Management Work Category

No.	Work Category	KPR %	KPA %	Deviation
1.	Preparation Work	6,84	7	0,155
2.	Building Demolition Work	8,29	8,5	0,202
3.	Land work	11,0	10,5	-0,54
4.	Concrate Work	16,74	15	-1,743
5.	Masonry Work	16,61	14	-2,615

Source: Copy of PT Royal Project Management project data from February – April 2025

Project delays can be minimized through the implementation of weekly mitigation and monitoring processes. This system relies on Business Intelligence (BI) as an early warning mechanism to detect potential deviations at an early stage. Based on the recap of work progress from February to April 2025, project performance exhibited variations across work categories, with several critical activities showing progress deviations. Although the project was only slightly behind schedule in aggregate, certain work categories demonstrated more significant delays that had the potential to affect the critical path and the overall project completion duration.

According to the results of internal interviews, project progress control has thus far been conducted through periodic evaluation meetings using reports manually compiled from Microsoft Project and Excel. This process is time-consuming, highly dependent on personnel accuracy, and not yet supported by an integrated dashboard capable of consistently presenting performance indicators in a near real-time manner. Consequently, performance deviations are often identified too late, resulting in delays in implementing corrective actions at the project site.

Previous studies on construction project time and cost control using Earned Value Management (EVM) methods as well as the application of Machine Learning (ML) have been widely conducted. Most EVM studies focus on performance evaluation and final evaluative projections rather than predictive early warning systems for subsequent periods. Likewise, many project dashboard implementations remain descriptive in nature and are not consistently supported by appropriate data management processes (Panchal, 2024). Research on ML in construction frequently focuses on general delay prediction, yet only limited studies have integrated periodic EVM indicators as structured variables for weekly project control (Schmitt et al., 2020). Meanwhile, Lean Construction is generally applied as a process improvement approach; however, it has not been widely operationalized as a corrective action recommendation module directly connected to predictive deviation outputs (Lestari & Adhirajasa, 2024).

Based on these gaps, the novelty of this study lies in the development of a Business Intelligence (BI)-based project control framework that integrates three analytical layers. Accordingly, this research proposes a Business Intelligence (BI) framework as an integrated project control system that combines descriptive, predictive, and prescriptive analytics. At the descriptive layer, project schedule data, cost budgets (RAB), actual expenditures, and WBS-based physical progress are integrated to generate Earned Value Management (EVM) indicators as representations of project performance. At the predictive layer, Machine Learning using the XGBoost algorithm is employed to predict deviations in subsequent periods as an early warning mechanism, with a focus on schedule performance indicators such as the actual Schedule Performance Index (SPI) and progress deviation profiles. At the prescriptive layer, the predictive outputs are linked to Lean Construction principles to formulate corrective action recommendations based on waste and constraint analysis, thereby enabling faster and more targeted field-level decision-making.

This framework is implemented in a Type-45 housing project as a representation of medium-scale construction projects in Indonesia, while also serving as an example of data-driven Smart Construction implementation aimed at improving schedule reliability and cost efficiency. This condition emphasizes that the timeliness and cost efficiency of construction projects affect not only company performance but also the effectiveness of national development initiatives.

1.2 Formulation Of The Problem

From the background of the above problem, the formulated problem is:

1. How to design a Business Intelligence (BI) framework for weekly project control that integrates schedule data, budget estimates, actual costs, and physical progress per WBS into consistent information?
2. How is the XGBoost model used to predict project performance deviations for the next period as an early warning based on EVM indicators?
3. How to connect the prediction results of the deviation with Lean Construction principles to formulate corrective action recommendations?

1.3 Research Purposes

In line with the formulation of the problem, the objectives of this research are:

1. To formulate and design a BI framework for weekly project control that integrates project data sources into EVM-based performance indicators.
2. To develop a predictive approach using XGBoost to predict time/cost deviations for the next period as an early warning based on EVM indicators.
3. To establish a mechanism for recommending corrective actions based on Lean Construction that is connected to the predicted deviation results, thereby supporting faster and more accurate decision-making.

1.4 Research Benefits

The benefits of this research are expected to provide significant contributions both theoretically and practically. The results of this research can be used for:

1. Theoretical Benefits
    a) This research contributes to the development of operational management and project management studies, particularly in time and cost control, thru the formulation of a Business Intelligence (BI) framework that integrates project data and presents it in the form of control information.
    b) The research findings enrich the literature on how EVM indicators support periodic control based on BI dashboards.
    c) This research adds references on the application of Machine Learning as a predictive approach based on project data and EVM indicators to support early warning detection of deviations in construction projects.
    d) The findings of this research expand the study of integrating analytical approaches with Lean Construction as a basis for formulating corrective action recommendations, so that the analysis results do not stop at reporting but are connected to process improvement.

2. Practical Benefits
    a) Providing a more structured and measurable overview of time and cost deviations based on EVM indicators at the WBS level and weekly.
    b) Providing a BI project control system design that helps management monitor project performance more quickly, objectively, and integratively thru a dashboard.
    c) Offering predictive tools thru Machine Learning models that can be used as a basis for early warning.

d) Serving as a practical reference for data-based control implementation that can be adapted by similar companies or other construction projects.
e) Providing learning contributions/case studies for the development of competencies in project data analysis, KPI formulation, dashboard preparation, and communication of system requirements with relevant parties.