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DEVELOPMENT OF AN ARTIFICIAL INTELLIGENCE–BIM FRAMEWORK FOR PREDICTING COST OVERRUNS AND PROJECT DELAYS IN NIGERIAN CONSTRUCTION PROJECTS A REVIEW OF PREDICTIVE EVIDENCE AND A PROPOSED INTEGRATION ARCHITECTURE

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ABSTRACT

Cost overruns and schedule delays remain persistent and well-documented problems in Nigerian construction projects, with underlying causes ranging from late material delivery and payment delays to poor contract management and adverse weather. Building Information Modelling (BIM) provides a structured digital repository of design, cost, and schedule data, while artificial intelligence (AI) and machine learning (ML) offer predictive techniques capable of forecasting delay and cost-overrun risk from historical project data. This paper reviews the empirical and conceptual literature on AI-based delay and cost-overrun prediction and on BIM adoption within the Nigerian construction industry, to propose an integrated AI–BIM framework. Drawing on eight sources published between 1994 and 2026, the review finds consistent evidence that late material delivery, poor decision-making, adverse weather, payment delay, and project complexity are the predictor variables most strongly associated with delay and cost overrun in the Nigerian context, and that machine-learning models, including ensemble and neural-network approaches, can predict delay risk from such variables with reported accuracy of approximately 85 percent in the best-performing comparable Nigerian study reviewed here, with ensemble methods shown to further improve on single-algorithm performance. At the same time, the review finds that

BIM adoption in Nigeria remains constrained by awareness, cost, and organisational barriers, meaning the structured data an AI-BIM framework would depend on is not yet consistently available in practice. The paper proposes a four-layer conceptual framework linking BIM and project data, feature engineering, AI/ML prediction models, and a decision-support and early-warning layer, and concludes that while the predictive and data-modelling components are each individually well evidenced in Nigeria, an empirically validated integrated AI–BIM framework has not yet been reported, and sets out directions for its future development.

KEYWORDS: Artificial Intelligence; Machine Learning; Building Information Modelling; Cost Overrun; Project Delay; Nigerian Construction Industry.

1. INTRODUCTION

Cost overruns and time delays are among the most persistent and costly problems facing the Nigerian construction industry. Foundational research on Nigerian construction projects identified financing and payment irregularities, poor contract management, material shortages, price fluctuation, and inaccurate estimates as major drivers of cost overruns, a diagnosis that later, more recent studies on the underlying causes of delay in Nigeria have largely reaffirmed, adding late material delivery, poor decision-making, and adverse weather as the most applicable factors. These recurring findings suggest that the problem is well understood at the level of cause, but that prediction and early warning, anticipating which specific projects are at elevated risk before overruns occur, remain comparatively underdeveloped in practice.

Two digital technologies offer a route toward such prediction. Building Information Modelling (BIM) provides a structured, information-rich digital model of a project's design, cost and schedule, in principle offering a ready-made data source for analysis. Artificial intelligence and machine learning, meanwhile, have been shown internationally and within Nigeria to predict construction delay risk from historical project data with high reported accuracy, using algorithms ranging from simple regression to ensemble and neural-network methods. However, the Nigerian literature on AI-based delay/cost prediction and the Nigerian literature on BIM adoption have so far developed largely as separate streams: predictive-modelling studies typically draw on survey or historical-record datasets rather than BIM models directly, while BIM-adoption studies focus on awareness and implementation barriers rather than downstream predictive use.

This paper addresses that gap. Its objectives are threefold: (i) to review evidence on the causes of construction delay and cost overrun in Nigeria and on the performance of AI/ML models in predicting them; (ii) to review evidence on the state of BIM adoption in Nigeria, as the data foundation an integrated framework would require; and (iii) to synthesise this evidence into a conceptual, four-layer AI–BIM framework, together with an agenda for its future development and field validation.

2. MATERIALS AND METHODS

This paper adopts a narrative review design, appropriate for synthesising literature spanning construction-management causal studies, machine-learning predictive-modelling studies, and BIM-adoption surveys, and for proposing a conceptual system architecture on that basis.

2.1 Search Strategy and Sources

Peer-reviewed journal articles, conference proceedings, and institutional repository records addressing causes of construction delay or cost overrun, AI/ML-based prediction of delay or cost outcomes, or BIM adoption and barriers, with explicit relevance to Nigeria, were located through academic search and repository platforms. Search terms combined "artificial intelligence," "machine learning," "BIM," "cost overrun," "construction delay," and "Nigeria," together with supplementary terms for specific algorithms (e.g., XGBoost, artificial neural network) and specific states.

2.2 Inclusion and Exclusion Criteria

Sources were included if they (a) examined causes or prediction of construction delay or cost overrun, or BIM adoption, within a Nigerian construction context, and (b) reported an identifiable empirical finding or model result. One foundational non-AI causal study (1994) was retained for its enduring relevance as the baseline diagnosis of Nigerian cost-overrun causes against which later predictive work can be read. Eight sources meeting these criteria, published between 1994 and 2026, form the evidence base summarised in Table 1.

2.3 Analytical Approach

For each included source, the focus, method, and principal finding were extracted and tabulated. Findings were grouped into three thematic strands: underlying causes of delay/cost overrun, AI/ML predictive performance, and BIM/AI adoption barriers. The causal findings were then mapped against the predictor variables used in the reviewed machine-learning studies to identify which real-world delay/overrun causes are, and are not, currently well represented as model features (Table 2). This mapping, together with the identified data-availability constraints, was used to construct the four-layer conceptual framework presented

in Figure 1 and the descriptive summary of reported model performance presented in Figure 2.

3. RESULTS

3.1 Overview of the Reviewed Evidence Base

Table 1 summarises the eight sources retained for synthesis. Five sources report primary survey or record-based empirical data collected in Nigeria (Lagos Island, Imo State, Enugu State, and multi-state consultancy firms in Abuja/Kaduna), two are methodological studies applying and comparing machine-learning algorithms to Nigeria-derived delay data, and one is the foundational 1994 causal study of Nigerian highway-project cost overruns. No source in the reviewed set reported an integrated AI–BIM system, in which a BIM model's own data directly feeds a delay or cost-overrun prediction engine, implemented and tested on a Nigerian construction project, confirming the framework gap this paper addresses.

Table 1. Summary of Reviewed Studies on Delay/Cost-Overrun Causes, AI/ML Prediction and BIM Adoption in Nigeria.

Study (Author, Year)	Focus	Method	Key Finding Relevant to This Review
Mansfield, Ugwu & Doran (1994)	Causes of delay and cost overruns in Nigerian construction projects	Survey of highway construction projects	Financing/payment of completed works, poor contract management, material shortages, price fluctuation, and inaccurate estimates are major overrun causes — the foundational Nigerian reference for this problem.
Egwim, Alaka, Toriola-Coker, Balogun & Oseghale (2021)	Extraction of underlying factors causing construction project delays in Nigeria	Expert survey; statistical/positivist analysis	Late delivery of materials by suppliers, poor decision-making, and inclement weather are the three most applicable underlying delay factors in Nigeria.
Egwim & Alaka (2021)	Comparative study of 27 machine-learning algorithms for predicting construction project delay	Expert-survey data; training/evaluation of 27 ML algorithms (EDMIC 2021, Nigeria)	Perceptron model was the top performer (accuracy, balanced accuracy, ROC-AUC and F1-score each ≈ 85%), exceeding all prior benchmarks reported for this task.
Egwim, Alaka, Toriola-Coker, Balogun & Sunmola (2021)	Applied artificial intelligence for predicting construction project delays	Ensemble-of-ensembles (stacking) predictive modelling	Ensemble machine-learning algorithms (bagging, boosting, naive Bayes) improve predictive force relative to single-algorithm models for delay prediction
Tunji-Olayeni,	Critical success	Quantitative survey,	Institutional, behavioural and

Aigbavboa & Oke (2023)	factors for the diffusion of AI in the Nigerian construction industry	Lagos Island construction professionals	cost factors are the most critical success factors for AI diffusion; knowledge, infrastructure, technical and trust factors also matter
Nnadozie, Amade & Enyinna (2026)	Adoption of AI on construction projects: awareness and current state in Imo State, Nigeria	Survey guided by Diffusion of Innovation theory	AI awareness exists among Imo State construction professionals, but practical, project-level implementation remains at an early stage.
Abubakar, Bala & Ibrahim (2014)	Barriers and drivers of BIM technologies adoption in the Nigerian construction industry	Questionnaire survey of design consultancy firms, Abuja and Kaduna (42.26% response rate)	Lack of [client demand/awareness] is identified among the leading barriers to BIM adoption, constraining the data foundation an AI-BIM framework would need
Aruma & Nnenanya (2025)	Enhancing building construction practices through AI and robotics	Descriptive survey, Enugu State, Nigeria (297 respondents)	AI-driven systems are perceived to improve precision and speed of construction processes; stakeholders should prioritise investment by area of greatest impact

3.2 Underlying Causes and Predictor Variables

Across the reviewed causal studies, a consistent set of factors recurs. The foundational 1994 study of Nigerian highway projects identified financing and payment of completed works, poor contract management, material shortages, price fluctuation, and inaccurate estimates as the major variables driving cost overrun. Nearly three decades later, a Nigeria-focused extraction of underlying delay factors, using expert survey and statistical analysis, identified late delivery of materials by suppliers, poor decision-making, and inclement or adverse weather as the three most applicable factors, and recommended that Nigerian stakeholders leverage the data produced from project schedules, as-built drawings, models, costs, and invoices, using AI or machine learning, to make key business decisions, and use climatological data to reduce the impact of adverse weather. This continuity between the 1994 and 2021 findings indicates that, despite three decades of digital advancement elsewhere in the industry, the fundamental causes of Nigerian construction delay and cost overrun have remained largely unaddressed at the level of everyday project practice.

3.3 Reported Performance of AI/ML Prediction Models

Where machine-learning approaches have been applied to Nigeria-derived construction-delay data, reported predictive performance has generally been strong. A comparative study training twenty-seven machine-learning algorithms on expert-survey data found that a

Perceptron model was the top performer, achieving an accuracy, balanced accuracy, ROC-AUC and F1-score each of approximately 85%, higher than any prior study of this kind and higher than the other twenty-six algorithms tested. A related study developed an ensemble-of-ensembles (stacking) predictive model, combining bagging, boosting and naive Bayes base algorithms, and found that ensemble methods improved predictive force relative to the use of any single algorithm for delay prediction. These findings are illustrated in Figure 2.

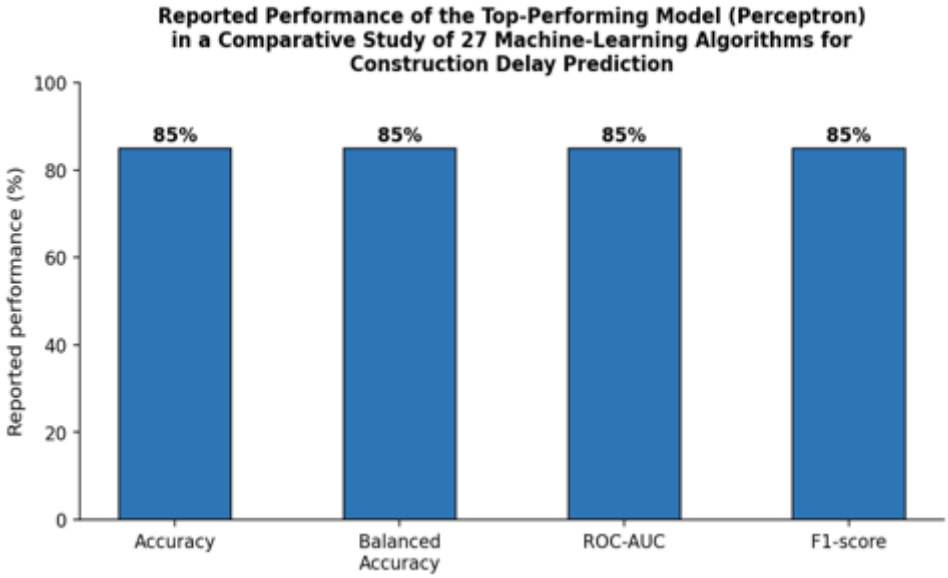


Figure 2 above shows the reported performance of the top-performing model identified in a Nigeria-based comparative study of twenty-seven machine-learning algorithms for construction-delay prediction.

3.4 BIM Adoption as the Data Foundation for an AI–BIM Framework

An effective AI–BIM framework presupposes that structured, reliable BIM data exists to feed the prediction engine. The reviewed BIM-adoption literature suggests this precondition is not yet consistently met in Nigeria: a survey of design consultancy firms in Abuja and Kaduna found that BIM's impact has not yet been strongly felt in the Nigerian construction industry despite its international recognition, with awareness and cost-related barriers limiting uptake. More recent surveys of AI awareness specifically, conducted in Lagos and Imo States, similarly found that institutional, behavioural, cost, knowledge, infrastructure, technical and trust factors all constrain AI diffusion, and that awareness of AI generally outpaces its practical, project-level implementation. Table 2 maps the delay/cost-overrun predictor variables identified in Section 3.2 against the data sources an AI–BIM framework would need

to capture them, illustrating both the framework's technical feasibility and its current dependence on wider BIM and digital-record adoption.

3.5 A Proposed AI–BIM Framework

Building on the predictor variables and model evidence reviewed above, this paper proposes the four-layer conceptual framework shown in Figure 1: a BIM and project-data layer combining the 4D/5D BIM model with historical project records and site/market data; a data-integration and feature-engineering layer; an AI/ML prediction-engine layer generating separate cost-overrun and delay/schedule-risk predictions together with ongoing model evaluation; and a decision-support and early-warning layer producing a predicted cost/time variance dashboard, risk-ranked alerts, and recommended mitigation or re-baselining options, with a feedback loop returning mitigation outcomes to the project database to retrain the models over time.

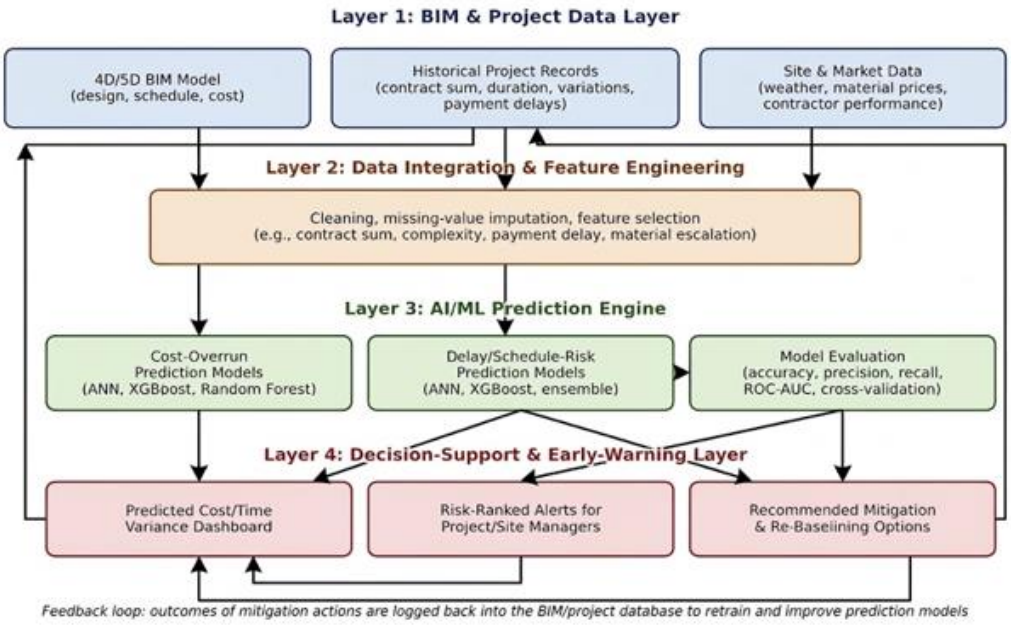


Figure 1 above presents the proposed four-layer AI–BIM framework architecture, from BIM/project data through to decision-support reporting and the model-retraining feedback loop.

Table 2 summarises how five key predictor variables identified in the reviewed causal literature map onto the data sources and framework layers described above.

Table 2. Mapping of Reviewed Delay/Cost-Overrun Predictor Variables to the Proposed AI–BIM Framework.

Predictor Variable	Source Evidence	Relevance to AI–BIM Framework
Late delivery of materials / material price escalation	Identified as a leading underlying delay factor (Egwim et al., 2021)	Feature drawn from BIM 5D quantities and linked market/price data feeds
Poor decision-making/contract management	Identified as a leading underlying delay factor (Egwim et al., 2021); poor contract management flagged by Mansfield et al. (1994)	Captured indirectly via variation-order frequency and payment-certificate lag in project records
Inclement/adverse weather	Identified as a leading underlying delay factor (Egwim et al., 2021)	Feature drawn from site weather sensing or meteorological records aligned to the BIM schedule
Contract sum, duration, and project complexity	Used as core predictor variables in ML delay-prediction studies	Directly extractable from the BIM model's cost and schedule attributes
Payment delay to contractor	Identified as a major cost/overrun factor (Mansfield et al., 1994); a predictor variable in ML delay studies	Requires linking BIM/cost-control data with the project's financial/payment-certificate records

4. CONCLUSION

The reviewed literature shows that the underlying causes of cost overrun and delay in Nigerian construction projects have remained remarkably consistent over three decades, spanning payment and financing irregularities, poor contract management, material shortages and price fluctuation, late material delivery, poor decision-making, and adverse weather. Separately, machine-learning approaches applied to Nigeria-derived project data have demonstrated strong predictive performance for delay risk, with top-performing models in the reviewed comparative study reaching approximately 85% accuracy, and ensemble methods shown to further improve on single-algorithm performance. However, the data foundation such predictive models would ideally draw on directly, namely structured BIM models, is not yet consistently in place across the Nigerian industry, with awareness, cost, and organisational barriers still limiting BIM adoption. This paper's proposed four-layer AI–BIM framework, linking BIM/project data, feature engineering, AI/ML prediction, and decision-support reporting, offers a conceptual bridge between these separately well-documented strands of evidence. Realising this framework in practice will require closing the BIM-adoption gap identified in the reviewed literature alongside the technical work of framework implementation and validation.

5. Research Directions

Building on the gaps identified in this review, four directions for future research are proposed:

1. Direct BIM-data model validation. Future studies should train and validate delay/cost-overrun prediction models using features extracted directly from BIM models (e.g., via Industry Foundation Classes) on Nigerian projects, rather than relying solely on survey-derived or externally compiled historical records as in the studies reviewed here.

2. Comparative algorithm benchmarking on BIM-linked data. Building on the strong reported performance of ensemble and Perceptron/neural-network models in survey-based Nigerian studies, future work should re-benchmark these and other algorithms specifically on BIM-linked datasets to determine whether performance is maintained, improved, or degraded when using structured BIM features.

3. BIM-adoption and data-readiness studies. Because an AI–BIM framework depends on consistent BIM data capture, further research should assess the practical data-readiness of Nigerian construction firms, that is, the extent to which usable, model-linked cost and schedule data is actually being generated and retained on live projects, not just BIM awareness or intention to adopt.

4. Field-pilot and mitigation-effectiveness studies. The proposed framework's decision-support and early-warning outputs should be piloted on live projects to test whether the recommended mitigation and re-baselining options measurably reduce realised cost overrun and delay relative to conventional project-control practice.

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