

Exploring Integration of Artificial Intelligence in Construction Bid Automation: A Review Approach

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Abstract

This paper explores artificial intelligence (AI) integration in construction bid automation. The literature review suggests that currently, construction firms generally rely extensively on manual processes to produce their technical and commercial bid proposals. The problem with this existing practice in many firms is that it often requires extensive manual inputs and resources to execute most of the activities in the process. However, there is often a relatively short bidding time frame, poor quality information, loss of organisational knowledge from staff turnover, and limitations to human ability. A literature review of 21 purposively selected relevant articles was carried out to explore AI applications, automation strategies, and digitalization efforts within the bidding process and to propose an AI-based theoretical bid automation model. The findings reveal that while AI has been applied to specific tasks such as cost estimation, risk assessment, and document analysis, no unified AI-driven framework exists for automating the bid preparation process in construction sector. The main contribution of the study to current knowledge and practice is the development of a theoretical bid automation model designed to minimize human input in the bid preparation process, which could serve as a blueprint for informing the actual development process of the model/tool. Such a model/tool will be handy in times/seasons when firms have a high volume of bids to prepare within short bidding timeframes, with limited human resources, and it is beneficial to draw on historical information from previous projects.

Keywords: Artificial intelligence, bid automation, construction bid automation, theoretical model

1. Introduction

In the construction industry, one of the strategies used by clients to award project work is the tendering or bidding process (Park *et al.*, 2021). This entails a process whereby a client will invite tenders from interested firms, and the firms use the information in the tender documents to prepare their bids/tenders which they submit to clients, normally in competition against others (Park *et al.*, 2021). This is akin to multiple shops providing quotes for a service, with the client choosing the most appealing offer. The bidding firms often follow a bid preparation process to develop their bid proposal. The bid preparation process often commences from the time of the bid notification to the time of bid submission (Manchanda, 2021; Laryea, 2022).

The bidding firms often follow a bid or tender preparation process to develop their bid proposal. The bid preparation process often commences from the time of the bid notification to the time of bid submission (Laryea, 2022). The technical and commercial teams in a construction firm typically follow their internal processes and execute various activities to prepare the bid. In current practice, the team(s) will typically prepare a technical and price proposal. The technical proposal will often comprise the methodology and technical resources to execute the work (Laryea, 2022). The commercial proposal will often include a price, which includes costs and markup.

Currently, construction firms generally rely extensively on manual processes to produce their technical and commercial bid proposals (Heo *et al.*, 2024; Li & Sun, 2024). The problem with this current practice in many firms is that it often requires extensive manual inputs and resources to execute most of the activities from start to finish. However, there is often a relatively short bidding time frame, poor quality information, loss of organizational knowledge from staff turnover, and limitations to human ability which often leads to the best possible bid submission rather than the optimal bid submission (Manchanda, 2021; Park *et al.*, 2021).

According to Manchanda (2021), Cusumano *et al.* (2022), and the research by Laryea (2009), based on a live observation of how contractors put a bid together, showed a significant reliance on manual processes and inputs from supply chain partners. The recent developments in AI applications offer a significant possibility to develop a tool that can assist in automating the bid preparation process to an extent that is practically possible, that is automating key automatable activities (Liu, 2022) that can assist in overcoming some of the challenges associated with the current way that firms prepare their project bids.

Therefore, the main argument in this study is that some of the key activities in current bid preparation practice may be capable of being fully or partially automated to assist firms in doing their bid preparation more efficiently and accurately. Hence, this paper explores

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artificial intelligence (AI) integration in construction bid automation and proposes a theoretical AI-based bid automation model.

2. Context of Automation in Bid Preparation

In the competitive landscape of the construction industry, bid preparation plays a pivotal role in securing projects. However, this process is often labour-intensive, time-consuming, and prone to human error. Consulting or construction firms must review complex project requirements, assess previous proposals, and customize submissions to meet the specific demands of clients. Given the complexity of the task, inefficiencies in bid preparation can lead to missed opportunities, increased costs, and delayed responses. A research study focused on automating the bid preparation process aims to address these challenges by leveraging advanced technologies to streamline bid preparation processes. The study seeks to assist consulting or construction firms in automating activities like extracting project details from bid documents, generating customized proposals based on historical data, and allowing expert review before submission. Such an approach is expected to not only enhance efficiency but also improve the strategic decision-making capabilities of firms in responding to project bids, ultimately giving them a competitive edge.

interactions, and underlying reasons. It serves as a preliminary theory guiding the research process, aiding in goal refinement, formulating relevant research questions, and the selection of suitable methodologies. It either explains graphically or in narrative form, the main things to be studied and the key factors, concepts, or variables; and the presumed relationships among them (Tamene, 2016). For this study on developing a bid automation model using artificial intelligence, some assumptions are made and these include; a) *some activities in the bid preparation process can be automated by leveraging new technologies like artificial intelligence*, b) *automating key activities of the bid proposal preparation process can increase process efficiency and reduce associated costs, time and errors in bid preparation*, and c) *leveraging historical bid data through AI techniques can enable firms to prepare future bids more accurately*. Based on these assumptions and concepts, a conceptual framework is developed. Figure 1 illustrates the conceptual framework, detailing the conceptual analysis process adopted to view automation integration into the bid proposal preparation activities. This conceptual framework serves as a foundation for understanding how automation can lead to greater efficiencies and more sustainable outcomes in the construction project bid preparation process.

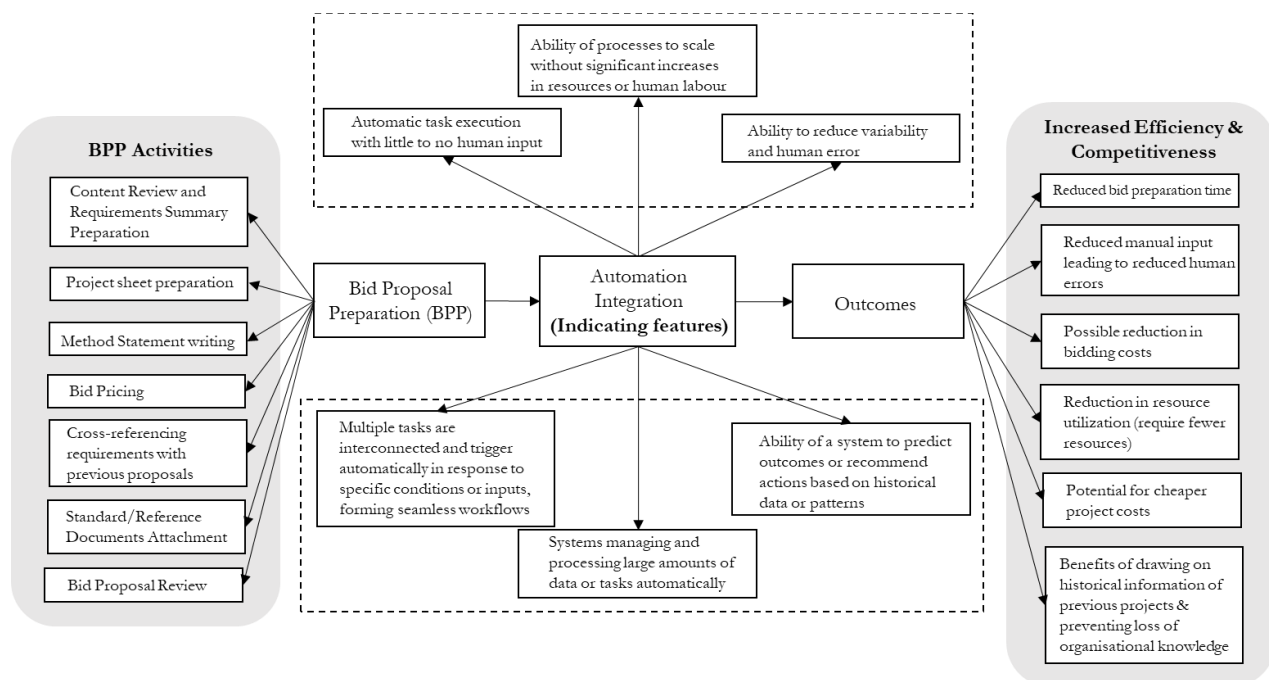


Figure 1: Conceptual framework of automation integration into bid preparation process

2.1. Conceptual Framework for Automation of Project Bidding

Maxwell (2022) emphasizes that a conceptual framework essentially represents the subject under study, outlining the elements involved, their

3. Research Method

Relevant literature on artificial intelligence (AI) integration in construction bid automation was purposively identified from academic databases,

including Scopus and Google Scholar. According to researchers like Hallinger and Kovacevic (2019); and Mongeon and Paul-Hus (2016), empirical research indicates that Scopus provides a broader range of sources compared to the Web of Science, particularly in fields beyond medicine and the physical sciences, making it suitable for construction-related research.

A total of 21 studies focusing on construction project bid preparation and automation were purposively identified and reviewed. The selection criteria emphasized studies that explored AI applications, automation strategies, and digitalization efforts within the bidding process. These studies provided a foundation for understanding the current state of automation in construction project bid preparation and identifying potential gaps where AI-driven solutions could be further developed.

Previous research indicates that construction bidding remains predominantly manual, with automation efforts primarily directed toward cost estimation, bid evaluation, and risk assessment (Cusumano *et al.*, 2022; Kim *et al.*, 2020; Park *et al.*, 2021). However, a comprehensive AI-driven model for bid preparation is notably absent in the existing literature. This study, therefore, sought to analyze existing automation efforts to establish a framework for integrating AI into the bid preparation process.

3.1. Analysis

The analysis involved a content review of the 21 selected studies, focusing on their contributions to AI integration in the construction bid preparation process. The reviewed studies provided insights into various automation efforts, highlighting both advancements and existing gaps in the field. These studies revealed key insights regarding the extent to which AI has been leveraged to enhance bid-related activities, including document analysis, decision-making support, and predictive modelling. This review has been instrumental in shaping the theoretical foundation for developing a comprehensive AI-based bid automation model.

3.2. Model Development

The proposed model for automating bid preparation will integrate artificial intelligence (AI) techniques, specifically designed to streamline key activities such as content extraction, bid/no-bid decision support, and automated proposal generation. The development process will begin with a comprehensive analysis of current bid preparation practices in construction firms to identify tasks that are suitable for automation. These tasks will be selected based on their repeatability and the availability of sufficient data for training AI models.

3.2.1. Data Pre-processing and Feature Extraction

Bid data will undergo a pre-processing phase to ensure its readiness for model training. This includes data cleaning (removing duplicates, and irrelevant information), text normalization (lowercasing, tokenization, etc.), and data transformation (such as converting documents into structured formats). Feature extraction will focus on extracting key attributes from tender documents, including project scope, requirements, deadlines, budget, and evaluation criteria. The extracted features will be used to create training datasets, which will represent the core attributes that the model needs to understand.

3.2.2. Model Selection and Training

For document parsing and requirements extraction, natural language processing (NLP) techniques will be employed. If bid documents are provided in scanned formats, Optical Character Recognition (OCR) will be performed using a third-party OCR engine (such as Tesseract OCR) to extract machine-readable text, which will then be processed using OpenAI's GPT-4o Mini large language model (LLM). Pre-processing steps such as format normalization, tokenization, stop word removal, and lemmatization will be applied to handle inconsistent formats, incomplete data, and unstructured text. The OpenAI embedding model (Ada-002) will be used to generate vector representations of past bid proposal documents, which will be stored in a vector database (Pinecone) to enable efficient semantic similarity searches using cosine similarity in identifying the closest match to the current bid. Named Entity Recognition (NER) will be used to extract key bid requirements.

The LLM will be used to generate bid recommendations and draft proposal content. The training datasets will include historical bid proposals, tender documents, and relevant project data, ensuring that the model learns to generate high-quality content that aligns with real-world expectations.

3.2.3. Validation Techniques

The model's performance will be validated through a combination of expert reviews, automated testing, and real-world simulations. Validation is crucial as industries and governments depend increasingly on predictions by computer models to justify their decisions (Sornette *et al.*, 2007). Initial testing will involve comparing the model's outputs to manually prepared bid proposals to assess accuracy, quality, and relevance. Expert feedback will be incorporated into the model through multiple iterations to refine its functionalities, including improving content extraction accuracy and enhancing the natural language generation (NLG) process. Validation metrics, such as precision, recall, and F1-score, will be used to evaluate the effectiveness of the feature extraction and bid proposal generation processes.

Additionally, user feedback on performance metrics, including processing time, error rates, and accuracy of extracted information, will be recorded to identify any limitations or areas for improvement and benchmarked against manual processes to assess the model's usability and impact on the bid preparation process.

4. Findings and Discussion

4.1. Review studies

A review of existing literature on automation integration into construction bid preparation highlights various research efforts across different focal areas. Table 1 presents an evaluation of these studies based on their specific automation areas of focus. The analysis reveals a growing interest in leveraging digital technologies to enhance efficiency in bid preparation, yet significant gaps remain in developing an automated bid proposal preparation model.

The Fourth Industrial Revolution (4IR) is largely centered on technology-driven automation and intelligent systems, with AI emerging as a fundamental enabler of these advancements (Sarker, 2022). However, building effective AI models remains difficult because of the complexity and variability of real-world data and problems. To address this, AI is categorized into several types: Analytical AI, which derives insights from data to support data-driven decision-making; Functional AI, which, unlike Analytical AI, executes actions rather than just providing recommendations; Interactive AI, which facilitates automated yet interactive communication, such as chatbots and virtual assistants; Textual AI, which encompasses natural language processing tasks like text recognition, speech-to-text conversion, machine translation, and content generation; and Visual AI, which focuses on computer vision and augmented reality applications.

Table 1: Areas of focus on automation integration into the construction bid preparation process

Automation areas of focus	Authors	No. of studies
Risk management	Tirmizi and Arif (2022); Choi et al. (2021); Park et al. (2021); Padhy et al. (2021); Kim et al. (2020); Huber and Imhof (2019); Pakgohar et al. (2013)	7
Bid Opportunities Identification	Lu et al. (2022)	1
Bid pricing	Heo et al. (2024); Li (2022); Kim and Jung (2019); Chou et al. (2015); Kandanala et al. (2005); Tavakoli Amir and Juliana Lano Utomo (1989).	6
Content Review Summary Preparation	Cusumano et al. (2022); Manchanda (2021); Cao et al. (2002)	3
Bid Selection and Evaluation	Chiu et al. (2014); Soroor et al. (2012); Chan et al. (2007); Ekström and Björnsson (2000);	4
Total number		21

While AI has been applied to specific tasks such as cost estimation, risk assessment, and document analysis, no unified AI-driven framework exists for automating the bid preparation process. Most studies focused on isolated automation efforts rather than an integrated approach.

These findings informed the theoretical model development, graphically presented in this study. The model outlines essential AI functionalities, including intelligent data extraction, and decision-support mechanisms, offering a structured approach to AI-driven bid automation.

4.2. AI-Based Modelling

This paper sought to explore the development of an AI-based bid automation model for firms in the construction industry. Achieving this, therefore, requires understanding and unbundling the activities involved in the existing process to a medium level of abstraction.

Machine learning (ML) is a highly promising AI technique that focuses on developing computer algorithms capable of automating the creation of analytical models (Sarker, 2021). These ML models typically consist of rules, processes, or complex transfer functions designed to identify meaningful data patterns or predict behaviors (Dua & Du, 2016). Machine learning, also referred to as predictive analytics, makes predictions about certain unknowns in the future through data, and is used to solve many real-world business issues, e.g., business risk prediction. Figure 2 illustrates a general framework for a machine learning-based predictive model, where historical data is used to train the model, enabling it to generate outcomes for new test data during the prediction phase. Depending on the specific problem domain, various

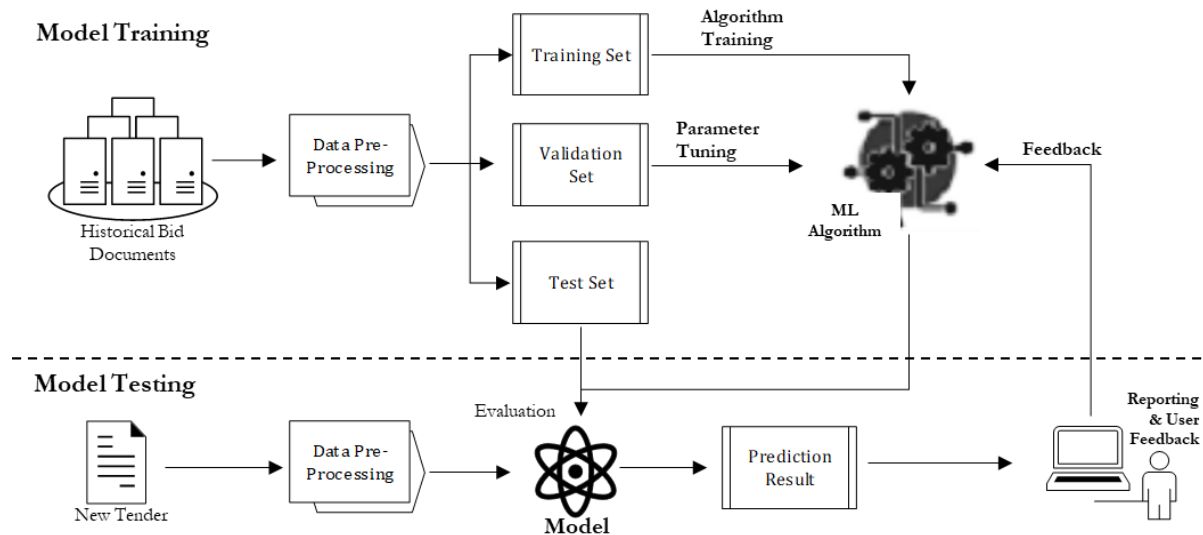


Figure 2: A general structure of a machine learning-based predictive model considering both the training and Testing phase

machine learning techniques can be applied based on their underlying learning principles and capabilities.

4.3. Theoretical Bid Automation Model

The purpose of this study is to develop an AI-based bid automation model for consulting firms in the construction industry. Achieving this, therefore, requires understanding and unbundling the activities involved in the existing process to a medium level of abstraction, which is capable of communicating important ideas and concepts about the bid automation model and informing the development process by serving as a blueprint.

4.3.1. Model Overview

The model is divided into three primary stages:

Content Review and Extraction: As shown in Figure 3, the extraction process will aid in the Bid/No-Bid decision-making by identifying key requirements from a document that assist management in evaluating whether to proceed with a bid (Manchanda, 2021). In this process, the user uploads the new invitation document through a user interface, usually in PDF format, and for scanned formats, Optical Character Recognition (OCR) will be performed using a third-party OCR engine (such as Tesseract OCR) to extract machine-readable text. The contents of the input document are extracted and separated into sections based on the various paragraphs within the document. These sections are then processed using a customized Natural Language Processing (NLP) engine, designed to extract the relevant requirements, such as the project type, scope of services, eligibility and evaluation criteria, and required documents to be submitted (Heo et al., 2024; Li & Sun, 2024).

NLP engine uses standard dictionaries, custom-made domain dictionaries and state-of-the-art deep learning neural network algorithms to identify the right set of requirements (Liu, 2022). Once these requirements are extracted, the requirements output file is displayed to the user/decision authority to support final Bid/No Bid decision-making. If the decision is No-Bid, the process terminates at this stage. However, if a Bid decision is made, the system proceeds to the next step of proposal preparation, by conducting a bid matching to identify the closest matches in the database.

Closest Bid Matching: Once a 'Bid' decision is made, the system begins searching for the most similar bid within the repository of historical bid documents. This matching process relies on Cosine similarity techniques to compare extracted requirements and identify the closest bid proposals. Based on this, relevant recommendations are generated using past bids. There are two possible outcomes: either a closely matching proposal exists in the database, or no suitable match is found.

Proposal Generation: Once close matches or a suitable match is found, they serve as the foundation for creating the new bid proposal documents. However, if no matching bid meets the eligibility criteria, the model generates the document using a predefined format from the database, incorporating information from the uploaded RFP. The new bid document is automatically drafted through a natural language generation (NLG)-based proposal engine (Liu, 2022), specifically utilizing a Large Language Model (LLM) for automatic bid proposal generation. The generated proposal is then reviewed by the bid preparation team of experts, and after several revisions, a final draft is prepared. Following the review process, the final bid proposal is

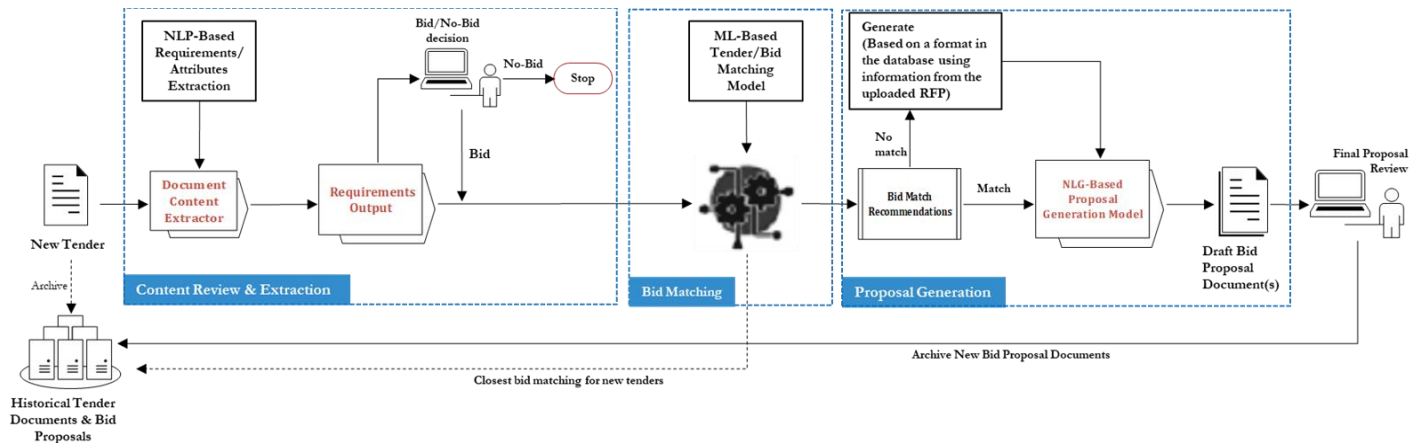


Figure 3: Theoretical AI-Based Bid Automation Model

submitted, and both the tender and the final proposal are archived for algorithm training and future use.

5. Conclusion and Further Research

This paper conceptualizes automation integration in the bid preparation process for construction firms, and proposes a theoretical artificial intelligence (AI)-based project bid automation model. The proposed AI-based bid automation model was depicted through a theoretical model that illustrated key phases, from content review and requirements extraction to bid proposal generation and recommendation. Each phase leverages AI-driven tools to reduce manual effort while enhancing accuracy, efficiency, and decision-making in bid submissions. Importantly, the “human-in-the-loop” feature integrated within the model ensures that critical tasks such as content review and bid proposal finalization retain the benefit of human oversight, providing a fail-safe mechanism to enhance the reliability of the automated outputs.

The main contribution of this study to existing knowledge and practice is the development of a conceptual bid automation model designed to minimize human input in the bid preparation process, which

could serve as a blueprint for informing the actual development process of the model/tool. Such a tool will be handy in times/seasons when construction or consulting firms have a high volume of bids to prepare within short bidding timeframes, with limited human resources. Thus, this proposed model is beneficial to draw on historical information from previous projects. Future research should focus on empirical validation and refinement of the proposed AI-based bid automation model, exploring its practical implementation in real-world construction firms, assessing its scalability, and evaluating its impact on bid quality, time efficiency, and cost reduction.

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