

A Systematic Literature Review on Cost Forecasting Techniques for Improving Estimates Accuracy in Construction Projects

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In construction, one measure of accuracy is the deviation obtained between estimate at completion and the most responsive tender figure. While different forms of forecasting techniques have been used, the era of artificial intelligence has also availed the industry the tools to improve construction cost estimation. However only a few studies address accuracy within the defined context of accuracy. The goal of this systematic literature review is to map out knowledge territory, highlight means of improving accuracy within the cost forecasting domain. From a total of 133 articles retrieved from EBSCOhost, Google Scholar, Scopus databases and ASCE library, 93 articles published between 1976 and 2022 were considered for the study. The review reports the contributions of extant literature which have so far focused on construction forecasting tools and techniques deployed to improve accuracy. A key highlight of the findings is that the reference to accuracy is given to models' ability to manipulate data (independent variables) and not in any sense comparing a final figure to one forecasted. This gap highlighted is the goal of an ongoing study aimed at examining current efforts at improving accuracy and thus developing an effective cost forecasting model using improved techniques. Through the analysis extant literature on cost forecasting, this review concludes that a robust big data analytics approach is needed to manage the shortcoming of existing techniques while taking into cognizance the series of events that are correlated and influence cost across the project life cycle. The review ends with a recommendation to consider a shift away from over-reliance on model development to training and operationalising models to adequately capture factors that influence cost overrun.

Keywords: Accuracy, cost forecasting, construction industry, forecasting techniques, modelling

INTRODUCTION

Forecasting cost for construction is one of the most important aspects when dealing with client expenditure management (Adafin *et al.*, 2017). In the last four decades, studies within the construction management discipline have advocated for accurate cost forecast. Yet, even as researchers consistently highlighted the dangers associated with inaccurate cost estimate, the tendency of the Estimate at Completion (EAC) overshooting the budgeted cost remains unresolved (Yussi & Latief, 2021). Authors like Flyvbjerg *et al.* (2002); Karaca *et al.* (2020) and Swei (2020) decry the rate at which the constructed facility fail to meet, inter alia, the budgeted cost.

Quite a number of studies have been published within the area of construction cost estimation. However, as systematic reviews are increasingly gaining acceptance as a starting point in the development of evidence-based knowledge (Siddaway *et al.*, 2019), only few number have focused on accuracy of construction cost forecast. Within the last decade, only about 5 articles published in scholarly journal is found to have carried out systematic review on construction cost estimation (Barakchi *et al.*, 2017; Dosumu *et al.*, 2022; Fazil *et al.*, 2021; Membah & Asa, 2015; Tayefeh Hashemi *et al.*, 2020). Two of the five focused on transport infrastructure (Barakchi *et al.*, 2017; Membah & Asa,

2015) while the other three focused on construction building and civil engineering projects. The review by Tayefeh-Hashemi *et al.* (2020) studied mainly machine learning techniques employed in cost prediction. Dosumu *et al.* (2022) in their study, developed a framework aimed at evaluating effective estimation processes using Nigeria as a case study. Fazil *et al.* (2021) in their bid to advance knowledge on cost estimation performance, addressed the nature of factors influencing cost estimation and how these factors have exerted their influence. Notwithstanding these research effort, the industry is seen been grappling with inaccuracies in cost forecast leading to cost overruns (Ahiaga-Dagbui & Smith, 2013). The novelty of this systematic review effective data management system can improve accuracy by means of robust techniques. Past studies have shown that reliable cost forecasting relies predominantly on historical data and leverage on certain criteria like clear definition of project scope (Fortune & Cox, 2005; *RICS New Rules of Measurement NRM 2 Detailed Measurement for Building Works*, 2013; Skitmore, 2002). As a way of making sense of the available vast scholarly information and highlighting gaps between what is known and what needs to be known, this systematic review seeks to address the following question with respect to construction cost forecasting:

- i. What has previous researchers done on construction cost forecasting?
- ii. What deficiencies have been highlighted in construction cost forecasting?
- iii. How does (1) and (2) above (the body of knowledge and deficiencies highlighted in cost forecasting) relate to data management?

CONSTRUCTION COST FORECASTING AND ACCURACY OF ESTIMATION

In 2020, Akinradewo *et al.*, (2020) in their bid to improving accuracy of road projects' estimates in the Ghanaian industry employed quantitative research design to highlight factors estimator should be given more attention for accuracy of estimates to be improved. Different methods have been employed for forecasting, for instance Bayram and Al-Jibouri (2018) used reference class forecasting for public building. Over the years, researchers have employed different techniques to develop tools with a view to improving the accuracy of cost forecasting. Among the numerous method ranging from single technique (Chen *et al.*, 2019; Juszczak *et al.*, 2018) to ensemble techniques (Kavzoglu & Teke, 2022; Park *et al.*, 2022), regression analysis and artificial neural network are the most predominantly featured methods representing between 40% and 25% respectively from the studies reviewed.

Accuracy in construction is the deviation obtained between estimate at completion and the most responsive tender figure (Morrison, 1984). Accurate means lack of error. It comprises two (2) aspects in terms of "bias" and "consistency" (Ashworth & Perera, 2015; Morrison, 1984; Skitmore, 1987). Bias is concern with the average differences between estimate and tender price according to arithmetical mean of percentage error (Skitmore, 1999; Skitmore *et al.*, 1990). The greater the average differences, the more bias the estimate. Consistency is the degree of variation around the average which means it measures how often the accuracy can be relied on (Ashworth and Skitmore, 1982). In theory, accurate estimation is the one closer to the tender price. However, this concept might raise some issues because overestimation could be rewarding due to persistent trend of overestimation in almost all QS practices (Cheung, 2005; Wang *et al.*, 2019).

RESEARCH METHODOLOGY

Review Procedure

There exist a number of guidelines outlining how to report systematic reviews and meta-analyses. However, for this study, the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) checklist is adopted since it most widely applicable across different research area and has gained inroad into construction related search and demonstrated in the study (Dosumu *et al.*, (2022).

Eligibility Criteria

The construction industry is sometimes considered as an amalgamation of several other industries like the processing and manufacturing industries. For inclusiveness, three pre-defined criteria were set. First, the article has to be published in construction related journal. Some of the journal titles known to be populated by construction cost estimation subject include Elsevier's "Automation in construction", "Procedia Engineering", "Journal of construction management" et cetera. on the other hand, articles which focus on cost estimation in other fields like nuclear, space, process or the manufacturing industry were not included. Secondly, only papers whose article were published in English language and are available in full-length for download is considered. In other words, publications, such as trade/labour union newsletters, research notes, editors' comments, readers' comment, and book reviews were excluded. The last criterion only applied to Scopus database; the selected articles were only limited to document type labelled (AR) meaning articles in final print. On the other hand, "Articles-in-Press (AiP), that is, pre-published versions of accepted articles were not considered. The reason for this is because AiP do not contain cited references which this review considers a vital source of information too.

Information Sources

In a bid to select relevant databases and academic libraries; four conventional databases, an unconventional AI-driven database -Dimension database - and 1 academic library was identified. It turned out that Google Scholar (GS), EBSCOhost and Elsevier's Scopus were selected among the 4, Web of Science database was excluded following the realisation that it is a subscription-based product and access to the database is only available to institutions who are subscribed to it. Observation revealed that the 3 selected database contained virtually all the journal article provided in Dimensions database, as a way to avoid reinventing the wheel, the Dimensions database was therefore removed from consideration. An initial search revealed that studies use terminologies like estimation, prediction, forecasting to convey the process of providing an estimate of probable cost of construction which in this case is represented by the term forecast. Care was however be taken not to trivialise the usage of term but rather to understand their usage as they appear on the articles and be treated on the study's merit. In determining keywords, a search configuration which include the different terms was used alongside the common Boolean operators. ("Cost Forecast*" OR "Cost Predict*" OR "Cost Estimate*") AND ("Models" OR "Modelling technique") AND ("Construction" OR "Construction industry"). A process flow of the systematic review methodology is presented in fig 1. Since the selected databases serves as repository for

literature cutting across different disciplines and geographical locations, it is envisaged that the process in its entirety will have avoided any bias geographically, considering that the earliest publication on model-based

cost forecasting dated back to early seventies with the work of (McCaffer, 1976; 1975), article sorting by date was between 1975-2022 (the year the review what carried out) will be used for the search.

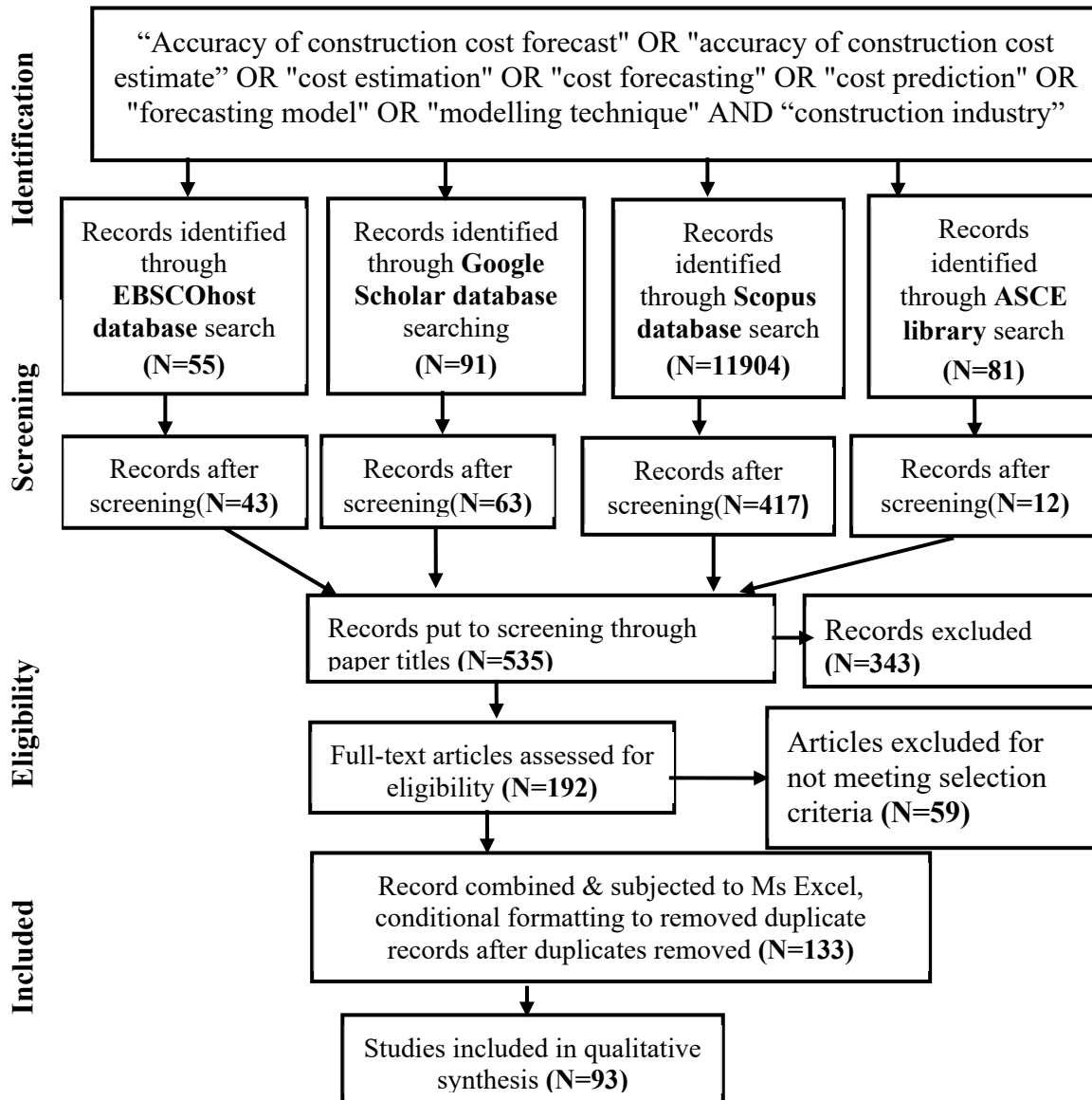


Figure 1: Flow chart illustrating the study selection process

Search Strategy

Search was conducted in the EBSCOhost database in addition with 3 others between 1st May, 2023 and 2nd May, 2023. The EBSCOhost database in particular presents an easy to use, user-friendly interface, once the university-based login details (ID and password) were provided and the webpage opened. To facilitate the search, the “Advanced search” button was used instead. This action redirect search to a new page with three dialogue boxes. However, only two dialogue box was used. To proceed, these search terms/phrase “accuracy of construction cost forecast” OR “accuracy of construction cost estimate” OR “cost estimation” OR “cost forecasting” OR “cost prediction” OR “forecasting model” OR “modelling technique” was typed into the first dialogue box while sticking to (TI Title) in the “select a Field” dialogue box beside the main search box. The phrase construction industry in inverted commas was typed into the second dialogue box. Only the Boolean “AND” was used between the two dialogue boxes which and turns 54 results. Unlike Scopus database, EBSCOhost provide an easy way to export every single record turned-out by the search to multiple destination including the MS Excel which was used in this case. By selecting all and de-selecting individual item that does not meet the inclusion criteria, a total of 43 papers were exported to Ms Excel. The search strategy on other database worked similar to EBSCOhost database except that those results of the search on Scopus were exported to a comma-separated values (CSV) file using the CSV Export option of Scopus Document search engine.

Data Collection Process

The process of carefully reading through each article titles facilitated the categorisation of all the papers into three themes in construction cost forecasting. In the course of the exercise, the author went through the articles and observed the presence and prevalence of certain words, theme or concepts that dominated each of the paper. Specifically, an Excel sheet was created so that the research topic, names of authors, research problem highlighted, theme, year of publication, and other information was captured. This is in tandem with Alaka (2017)’s study which summarises findings for their systematic review in a table form. From this process, five articles which also embarked on a systematic review focusing on cost estimation was documented.

Study Selection

Entering the key words “accuracy of construction cost forecast” OR “accuracy of construction cost estimate” OR “cost estimation” OR “cost forecasting” OR “cost prediction” OR “forecasting model” OR “modelling technique” AND “construction industry” on the Elsevier’s database as the search criterion resulted in 11,904. This initial result was trimmed down to 417

after a refinement process was carried out on the basis year of publication, article type, journal publication title, subject area and access type. The subject area option included Engineering, Energy, Environmental sciences, Economics, Earth, Decision science and mathematics. Among these, only the first three were ticked. The journal titles selected included International journal of forecasting, Expert systems with application, Procedia computer science, Automation in construction, Energy and building and finally, Energy Procedia. From the records obtained, further 274 of the retrieved articles were excluded as they were unrelated to construction industry research. By applying the eligibility criteria, reading article title and abstract, 47 articles were obtained. However, one of the limitations has to do with inaccessibility to certain databases because the authors’ affiliated university is not subscribed to them. This left a total of 23 published articles from Scopus database which was added to the screened ones from other database to make up a total of 93 articles which was considered for analysis in this review.

RESULTS

Study Characteristics

Table 1 summarises techniques employed in previous studies to improve accuracy of forecast. Effort to improve forecast accuracy span over 4 decades. Over the years, researchers have employed different techniques to develop tools with a view to improving the accuracy of cost forecasting. Chronologically, these studies can be partitioned

into two segments. For the period between 1990 – 2010, out of a total of 15 articles, Regression techniques (Attalla & Hegazy, 2003; Lowe *et al.*, 2006) and Artificial Neural Network (ANN) (Elhag & Boussabaine, 1998; Kim *et al.*, 2004; Wilmot & Mei, 2005) were the most predominantly featured tools representing between 40% and 25% respectively. Others include case-based reasoning (CBR) (Kim *et al.*, 2004), support vector machine (SVM) (An *et al.*, 2007) and a combination of genetic algorithm (GA) and ANN (Kim *et al.*, 2004). Regression was introduced in the earlier years as a means to forecasting construction cost, more so, its growing appeal came from its strong analytics and predictive potential at improving estimate’s accuracy by using log derivative. As research continued on an increasing trajectory, ANN was introduced in cost forecasting as a means of managing large datasets and tackling restrictions imposed by non-linear relationships and assumptions.

Table 1: Cost forecasting techniques/approaches literature matrix

ID No	Article Title	Reference	Problem	Model theme	Estimate stage	Techniques
T43	Model for Forecasting Highway Construction Cost	Herbsman (2006)	Lack of suitable tool to evaluate future road cost	Parametric	Stage 0	Time series
T4	Development of a Maintenance and Repair Cost Estimation Model for Educational Buildings Using Regression Analysis	Kim <i>et al.</i> (2006)	Absence of facility management-based cost estimation model	Parametric	Stage 6 & 7	Regression Analysis
T27	Construction cost prediction model for conventional and sustainable college buildings in North America	Alshamrani (2016)	Absence of college buildings preliminary cost prediction model	Parametric	Stage 0	Regression model
T36	Prediction Algorithm of Bridge Construction Cost Based on Regression Analysis	Yang & Qiu (2020)	Existing cost prediction models ignore correlation between the variables that affect cost	Parametric	Stage 0	Regression analysis
T33	Initial cost forecasting model of mid-rise green office buildings	Alshamrani (2020)	Model for forecasting green buildings early cost is non-existent	Parametric	Stage 0	Linear regression
T30	Cost forecast model for sewer infrastructure	El-Assaly <i>et al.</i> (2006)	Absence of predictive template for effective cost management of sewer infrastructure	Parametric	Stage 0	Logit regression model
T37	Predicting Construction Cost Using Multiple Regression Techniques	Lowe <i>et al.</i> (2006)	Lack of time-tested methodology to predict cost of UK buildings	Parametric	Stage 0	Multiple Regression Analysis
T8	Exploring Regression Models for Forecasting Early Cost Estimates for High-Rise Buildings	Ofori-Boadu (2015)	Paucity of forecasting model for High-Rise Buildings	Parametric	Stage 0	Multiple regression model
T22	Early cost estimating for road construction projects using multiple regression techniques	Mahamid (2011)	Non deployment of conventional cost predictive tool for road projects	Parametric	Stage 0	Multiple regression methodology
T17	Forecasting Completed Cost of Highway Construction Projects Using LASSO Regularized Regression.	Zhang <i>et al.</i> (2017)	Absence of model that harness economic factors & project-related variables for highway projects estimation/Lack of estimating system that's better at, handling multi-collinearity, feature selection and numerical stability	Parametric	Stage 0	Least Absolute Shrinkage & Selection Operator (LASSO) regression

T25	Predicting accuracy of early cost estimates using factor analysis and multivariate regression	Trost & Oberlender (2003)	Non-existent methodology that optimally assess factor affecting the estimate accuracy	Parametric	Stage 0	Factor analysis and multivariate regression analysis.
T7	Project cost prediction model using principal component regression for public building projects in Nigeria	Ganiyu & Zubairu (2010)	Rarity of factors influencing cost overrun in public projects	Parametric	Stage 0	Principal component Regression
T49	Neural network model for parametric cost estimation of highway projects	Hegazy & Ayed (1998)	Non-existent simple & user-friendly cost predictive model for high way projects	Parametric	Stage 0	Neural network, Genetic Algorithm
T16	Comparison of construction cost estimating models based on regression analysis, neural networks, and case-based reasoning	Kim <i>et al.</i> (2004)	Effectiveness of the estimating models in terms of estimation accuracy remains unclear	Parametric & AI	Stage 0	MRA, NN, CBR
T21	Predicting Cost Deviation in Reconstruction Projects _ Artificial Neural Networks versus Regression	Attalla & Hegazy (2003)	Lack of predictive cost deviation tool in reconstruction projects	Parametric & AI	Stage 0	Statistical analysis, and artificial neural networks
T26	Construction cost forecasting: comparison of the accuracy of linear regression and support vector machine models	Petruseva <i>et al.</i> (2017)	Non-existent evaluation of forecasting models' effectiveness	Parametric & AI	Stage 0	Linear regression; support vector machine
T38	Predicting completed project cost using bidding data	Williams (2002)	A method that uses competitive bid figures for cost prediction is lacking	Parametric & AI	Stage 4	Linear regression, Neural network

DISCUSSION

Information extracted from the 93 articles reviewed was classified into articles title, authors names, articles' year of publication, problem identified, theme, tool's application stage, specific technique/approach applied for forecasting cost. It is evident that techniques have been employed in forecasting cost for about four decades ago (Herbsman, 1986). Currently, most field can be revolutionised if the right analytic tool is used on relevant large datasets (Ahiaga-Dagbui & Smith, 2013; He *et al.*, 2021). Studies has also shown that predicting future performance based on available past data is of great importance (Hou, 2016; Huang *et al.*, 2021). Predicting based on past data is not only crucial to business success, but also inevitable in today's competitive economy. Therefore, construction industry is not an exception too. As noted by (Arafa & Alqedra, 2010) cost estimation in the early stage of the project, when there neither exists enough information nor the scope of work is finalized, has a major impact on initial decision-making issues in construction projects. Providing clients or project managers with accurate cost estimations prior to start of the project will assist them to consider adequate and appropriate alternatives. As projects progress, the level of accuracy increases due to more information being available (Chen *et al.*, 2019). Conventional methods of predicting projects' costs are known to be faced with several deficiencies, including inability to diagnose complex interrelationships between a number of existing variables, neglecting inevitable uncertainties and therefore, incapability of reaching reliable forecasted final cost (Alex *et al.*, 2010; Arabzadeh *et al.*, 2018; Attalla & Hegazy, 2003). In return, artificial neural networks with their successful experience in forecasting diverse problems are among the most accurate and trustworthy used models (Alex *et al.*, 2010). Their ability to learn from incomplete datasets in order to predict the unseen section of data besides their capability of modelling the problem with the least available data and estimating almost all continuous functions, have made them attractive enough to be used in prediction problems (Chimdi *et al.*, 2020; Murat Günaydın & Zeynep Doğan, 2004). Neural networks' forecasting process is divided into two sections. In the first section, the network is provided by a set of data containing inputs and desired outputs and in the second part, it tries to tune its parameters, including weights and biases to reach desired output by minimizing the difference between the generated output

and desired output known as the target in each iteration (Matel *et al.*, 2022; Sitthikorn Sitthikankun, 2021).

A careful review of literature within the cost forecasting domain reveals two fundamental aspect which make for convenient classification of past studies namely factors and approaches. The first relates to studies which argue that the consideration of certain variables often regarded as factors and their appraisal is fundamental to achieving reliable forecasting. They argue and, in some case, demonstrate that taking into cognizance certain factors which may influence the final cost can forestall cost overrun when implementing other projects (Akintoye, 2000; Babalola & Abiodun Adesanya, 2008; Jumas *et al.*, 2015; Lim *et al.*, 2016). While it is important to take into account the unique features of project that may pose cost variability, the narrative that their consideration in isolation can deliver accurate cost forecast cannot be sustained. Both previous and recent study like that of Abdel-Monem *et al.* (2022), Dandan *et al.* (2020), Babalola and Adesanya (2008), Dosumu, (2022), Karaca *et al.* (2020) and Lim *et al.* (2016) have come up with list of factors. A Careful analysis of 24 articles - representing 23% of total articles obtained for review; synthesises a total of 54 factors. Whereas some studies went further to classify the factors and related their impact to specific stage within project lifecycle (Dandan *et al.*, 2020), others only stopped at identifying the factors and signpost crucial factors that must be taken into account in order to produce accurate forecast. In a pioneering attempt, Akintoye (2000) put forward seven principal components of cost influencing factors. According to the author, these seven sub-categories include project complexity, technological requirements, project information, project team requirement, contract requirement, project duration and market requirement. Apparently most successive study falls within this frame in their categorisation. For example, Babalola and Abiodun Adesanya (2008) submit that the four principal factors affecting production of cost estimate for electrical services in Nigeria include estimator's experience, project technicality, economic requirement and contract requirement. In practice, achieving an accurate forecast does not rely solely on establishing the factor but on how they are being handled. While it is not advisable that any of these factors be ignored, their consideration alone do not function to guarantee accurate cost estimate. Figure 2 show the tabulation of articles related to factors influencing cost.

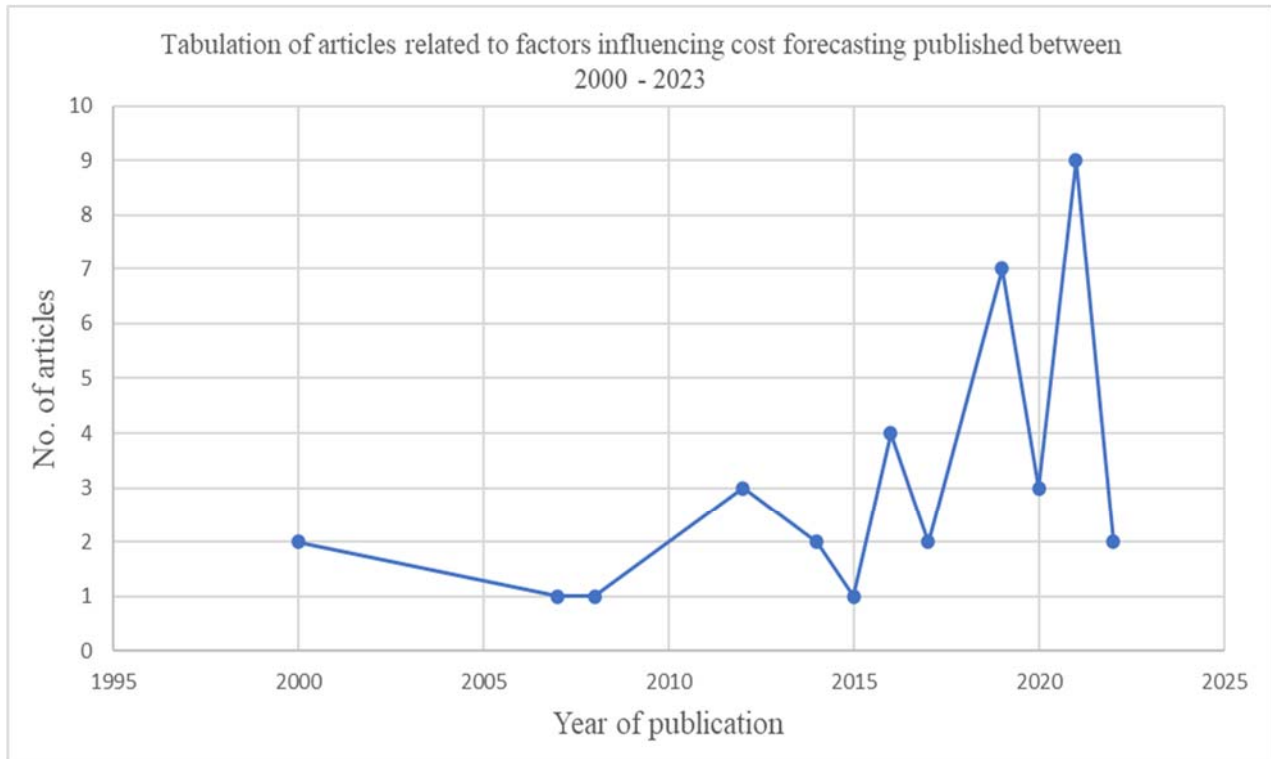


Figure 2: Factors influencing cost related articles published between 2000-2022

Secondly, the need for accurate and reliable cost forecasts in the construction industry has manifested through studies which contend that the right approach to cost estimation will deliver accurate forecast. A total of 71 articles which represent 77% of the total papers obtained have put forward different method with a view to achieve this goal. The effectiveness of these methods is demonstrated by the development and deployment of different technique and models respectively. From this vantage point, many authors have reported that accuracy have been improved upon (Bayram & Al-Jibouri, 2016; Hashemi *et al.*, 2019; Swei, 2020; Tas & Yaman, 2005). The analysis of the articles reveals certain classifications of estimating techniques, some of these include top-

bottom, bottom-top, intelligent systems techniques, analogy technique, traditional and parametric techniques etc. For the purpose of this review, they can best be classed into parametric and artificial intelligence estimating techniques (Elmousalami, 2020). The development of traditional model dates back to early 1960s; today, literature records a list of over 28 cost forecasting model. These studies across-board highlight the use of data from historical projects. The models themselves rely heavily on data as variables to mimic the features within the system they forecast. Figure 3 show the tabulation of articles related to techniques adopted to improve forecast accuracy.

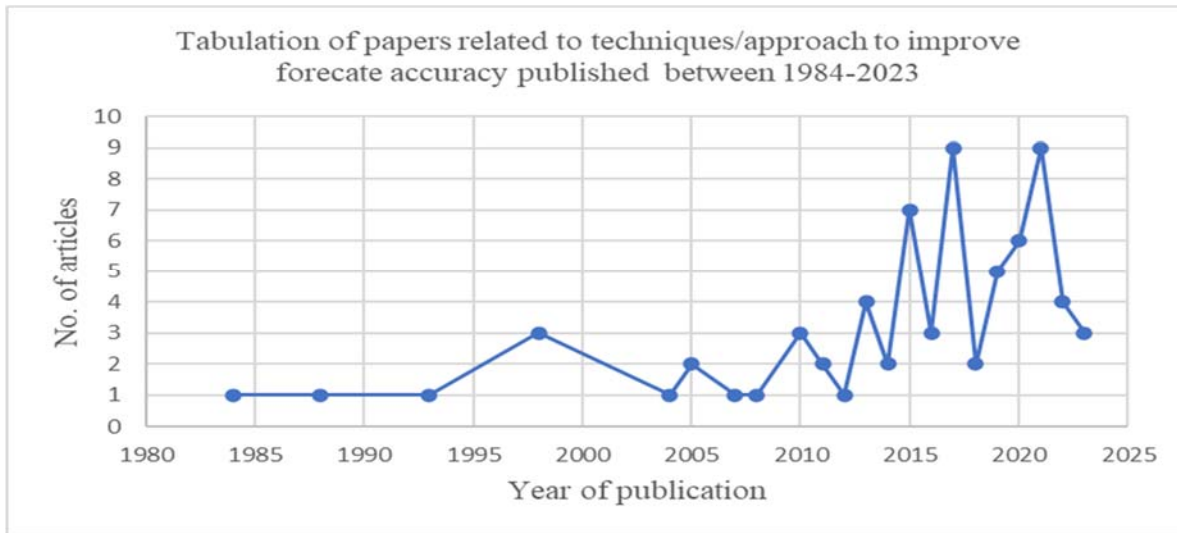


Figure 3: Techniques developed to improve forecast accuracy published between 1984-2023

CONCLUSION

From evidence in the reviewed literature, this systematic review affirms that construction cost forecasting plays a valuable role in dealing with client expenditure. However, owing to the lack of data and information at the early stage, the construction industry has been grappling with inaccuracies in cost forecast. Different approaches, techniques and tools have been developed to address this problem. Yet, proven cases of cost overrun still exist. One of the reasons identified is due to lack of interest in forecasting process and the data management. These aspects if not given due consideration, will only leave researchers scrambling for answers regarding the performance of accurate forecast. In most cases the R^2 and MAPE (mean absolute percentage error) are used as estimators of the accuracy of the predictive models. In statistics, the coefficient of determination R^2 measures the general suitability of the predictive model, indicating how good data points match a curve or a line. The values of R^2 belong to the interval $[0,1]$ and expressed in percent R^2 computes how much the variation of the output response is attributed to the predictors of the model (Petruşeva *et al.*, 2017). The accuracy they are looking at is not in any sense comparing a final outcome to a forecasted one, (say final and budgeted cost) rather the accuracy which has to do with the model’s ability to manage the data with which is being developed. This explains why most of the studies are seen to be compare accuracy measures like mean absolute error, mean square error etc. this has nothing to do with its ability to predict something being accurate. From the analysis extant literature on cost forecasting, this review concludes that a robust big data analytics approach is needed to manage the shortcoming of existing techniques while taking into cognizance the

series of events that are correlated and influence cost across the project life cycle. The review ends with a recommendation to consider a shift from over-reliance on model development to training and operationalising models to adequately capture factors that influence cost overrun.

LIMITATIONS

This review also presents a number of limitations; some of them, for example, concerns the choice of journals which represent studies focusing on the key words and research question. While journals are important platforms to disseminate research, it needs to be stated that cost management knowledge can also be circulated in other channels, such as books, conference papers and thesis. Since material retrieved and reviewed did not include such, this analysis admits the limitation that could come thereof. Moreover, this study only focused only on English-speaking systems during the search/query which obviously are not representative of other vast body of knowledge conveyed through other languages.

As with the review outcome, this analysis observes that some models employed for forecasting cost cannot be said to be based on construction process criteria and do not fully take into account the uncertainties peculiar within the construction process. Even though significant research has been published on this topic of cost estimation, the understanding of the underlying causes of inaccurate estimate and a clear direction towards improvement remained unexplored. Sound forecast need to be anchored on historical performance of other construction projects. Finally, it was also noticeable that though different factors, forecasting techniques and conceptual model has been investigated and put

forward; till date, no single study exist which harmonise all these aspects to form a template to bring all these issues into consideration. This is not surprising as the fragmented landscape of the construction industry seem to explain the situation.

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