

Developing a Cost Estimating Conceptual Framework that Leverages on Knowledge

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Abstract

Literature on the accuracy of cost estimates in construction projects has reported that attempts to improve accuracy were focused on the methods, tools/techniques, and the factors affecting accuracy. This confirmed that attempts at addressing these inaccuracies were based on reductionism. To avert these inaccuracies, there is a need to go beyond reductionism and adopt a multi-theoretical approach, such as leveraging knowledge. This paper reports the effort made to incorporate different and relevant theories to develop a framework that would be used to improve accuracy. A systematic literature review was used to identify and examine factors that affect leveraging knowledge within the cost estimating process. The factors include: cost estimating process models, factors affecting accuracy, information and knowledge required for estimating. Relevant theories were then used to underpin the concepts and finally develop the conceptual framework. The paper is one step in a larger study aimed at developing a knowledge-based cost estimating process model for construction projects. The developed framework will bridge the gap between research and practice. It provides a structured approach to cost estimating and improves the accuracy of estimates. The framework will enhance research rigour, foster advancements in cost estimating methodologies, and inform industry best practices.

Keywords: Accuracy, Cost Estimates, Conceptual Framework, Knowledge and Projects

1. Introduction

Cost estimating plays a crucial role in construction projects as it forms the foundation for informed decision-making throughout the project lifecycle (Valtanen, 2020). Accurate cost estimates are vital for determining project feasibility, securing funding, and ensuring project success (Akinradewo, Aigbavboa & Oke, 2020; Jiang, 2020). However, achieving accuracy in cost estimating has been a persistent challenge in the construction industry. Inaccurate estimates can lead to misallocation of resources and project failures (Ibrahim & Elshwadfy, 2021; Albtoush *et al.*, 2022). Inaccurate estimates can have detrimental consequences, leading to budget overruns, delays, and disputes between stakeholders (Egboga, Daniel, & Abubakar, 2022).

The construction industry has been grappling with cost estimating accuracy issues for decades, with slight improvement in accuracy levels (Dandan, Sweis, Sukkari & Sweis, 2019; Chimdi, Girma, Mosisa & Mitiku, 2020). This persistent challenge has spurred research efforts to improve cost estimating practices. Attempts made at improving the accuracy of cost estimates focused essentially on methods, or tools and techniques, and the factors affecting accuracy (Fazeli *et al.*, 2020; Hashemi *et al.*, 2020; Khodabakhshian & Toosi, 2021; Ning *et al.*, 2020). While inaccuracies in cost estimates have remained unabated, attempts to address them are based on a reductionist approach by examining the various factors that affect the accuracy of estimates (Wang *et al.*, 2022; Sayed *et al.*, 2023; Chimdi *et al.*, 2020; Egboga *et al.*, 2022). Therefore, calls have been made to go beyond the reductionist

approach and adopt a multi-theoretical approach, such as leveraging Knowledge (Kumar *et al.*, 2021; Areed *et al.*, 2021). Existing cost estimating process models are information-centric instead of being knowledge-centric; as such, they are not capable of handling the paucity of information at early stages of construction projects (Albtoush *et al.*, 2022; Chimdi *et al.*, 2020; Ibrahim & Elshwadfy, 2021). Therefore, there is an absence of a mechanism that leverages knowledge within the existing process models.

This study is a part of a larger study that aims to develop a process model that leverages knowledge within the cost estimating process to improve the accuracy of cost estimates for construction projects. To achieve the aim of the study, five objectives were formulated. First to identify factors that affect the leveraging of knowledge within cost estimating process, secondly to develop a cost estimating conceptual framework that leverages on knowledge; Thirdly, to assess cost estimating practices in construction projects, Fourth, to determine the requirements for leveraging knowledge within the cost estimating process and lastly to develop and implement the knowledge-based cost estimating process model.

This paper addresses the first and second objectives of the larger research. Therefore, to be able to achieve the aim of this research paper, the study identified factors that affect the leveraging of knowledge within cost estimating process, it undertakes a systematic and critical literature review to specifically understands the Cost estimating Process, Factors affecting accuracy of cost estimates, information required for cost estimating and knowledge required for improving cost estimate

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accuracy, and finally developed the cost estimating conceptual framework that leverages on knowledge by, understanding theories that underpins the research, understand the concepts/constructs to be investigated, relate theories to the study constructs and then establish interrelationships between the study constructs. The conceptual framework will help identify the practice in Quantity surveying Firms and also help in the development of the final model.

2. Literature Review

2.1. Existing Cost Estimating Process Models

There is a necessity for a standardised guide for cost estimating practitioners to ensure uniformity and consistency in estimate preparation. Several cost estimating process models exist. A current review of the literature points us to three readily available guides, which are specific to industries in the UK and U.S. These guides are considered "best practices" from the UK and U.S. Studies relating to cost estimating have focused on methods and techniques most of which are outlined in the New Rules of Measurement (NRM) 1 (RICS, 2009). These process models guide estimators to prepare accurate estimates. Subsequently, more organisations like RICS (2020) and NASA (2008) have since published a set of steps. To reinforce the importance of an accurate conceptual cost estimate, authors like Kirkham (2015) and Ashworth & Perera (2015) have also extensively examined the order of cost estimate.

2.1.1. Department of Energy (DOE) cost estimating process model developed in the U.S.

The U.S. Department of Energy (DOE), through collaborations, developed a 12-step process model recommended by the Government Accountability Office (GAO) to serve as an estimating guide for capital projects. The DOE model comprises 12 steps, which can be divided into three stages. Pre preparation consisting of five (5) steps (Define the Estimate's Purpose, Develop an Estimating Plan, Define the Program Characteristics, Determine the Estimating Structure, Identify Ground Rules and Assumptions); preparation stage consisting of four (4) steps (Develop a Point Estimate, Compare to Independent Estimate, Conduct sensitivity analysis, Conduct Risk & Uncertainty Analysis) and post preparation stage consisting of three (3) steps (Document the Estimate, Present Estimate to Management for Approval, Update the Estimate to Reflect Actual Costs and Changes).

2.1.2. The Infrastructure Project Authority (IPA) process model was developed in the UK.

The IPA document provides a best practice approach to cost estimating for UK infrastructure projects. It is designed for project leaders and delivery teams to improve estimate quality and decision-making. The process involves eight steps divided into three stages:

pre-preparation, preparation, and post-preparation. This guidance aims to enhance project delivery and benefit UK citizens. The process consists of eight (8) steps classified in to 3 stages as well including the pre-preparation steps consisting of one (1) step (Establish brief and engage the team), the preparation steps consisting of three (3) steps (Gather data and evidence, Select cost estimating methodology, Calculate base cost estimate, uncertainty, risk) and the post preparation steps consisting of (4) steps (Produce cost estimate report, Review and assure, Project leadership sign-off, Use the cost estimate to support decision- making).

2.1.3. New Rules of Measurement (NRM) 1 Order of Cost Estimates from Handbook of Cost Management

NRM also has 13 steps, the Pre-Preparation Stage having 1 step (Basic information gathering), the Preparation Stage with 10 steps (Produce building work estimate, Ascertain work cost estimate, Produce project and design team fees estimate, Produce development and project cost estimate, Ascertain base cost estimate, Produce risk allowance estimate, Ascertain cost limit exclusive of inflation, Produce inflation estimate, Ascertain cost limit inclusive of inflation, Produce VAT assessment) and Post-Preparation Stage having two steps of activities (Produce order of cost estimate report, Issue order of cost estimate report).

2.2. Factors affecting the accuracy of cost estimates

A review of 73 studies reveals the existence of 160 disaggregated factors, as reported by Musarat et al. (2021), Albttoush et al. (2021), Dandan et al. (2020), and Chimdi et al. (2020). These factors were then critically reviewed and studied to reveal 58 aggregated factors across the literature (Dandan et al., 2020; Chimdi et al., 2020; Albttoush et al., 2021). The criterion used to reduce the factors was based on the fact that some of the factors repeated themselves across different authors. Out of these 58 factors, 22 are knowledge-related while 20 are process-related. Within the process-related factors, 13 are about information (See Table 1 in the Appendix).

These factors are considered to affect the accuracy of an estimate. Authors have tried to group the factors into five groups: Group A, client-related factors; Group B, consultants, design, and information-related factors; Group C, cost-evaluation procedure-related factors; Group D, project attributes-related factors; Group E, contract and offering-related factors; and Group F: Market and External condition-related factors. However, the top 10 based on the research requirements were selected and used for the framework.

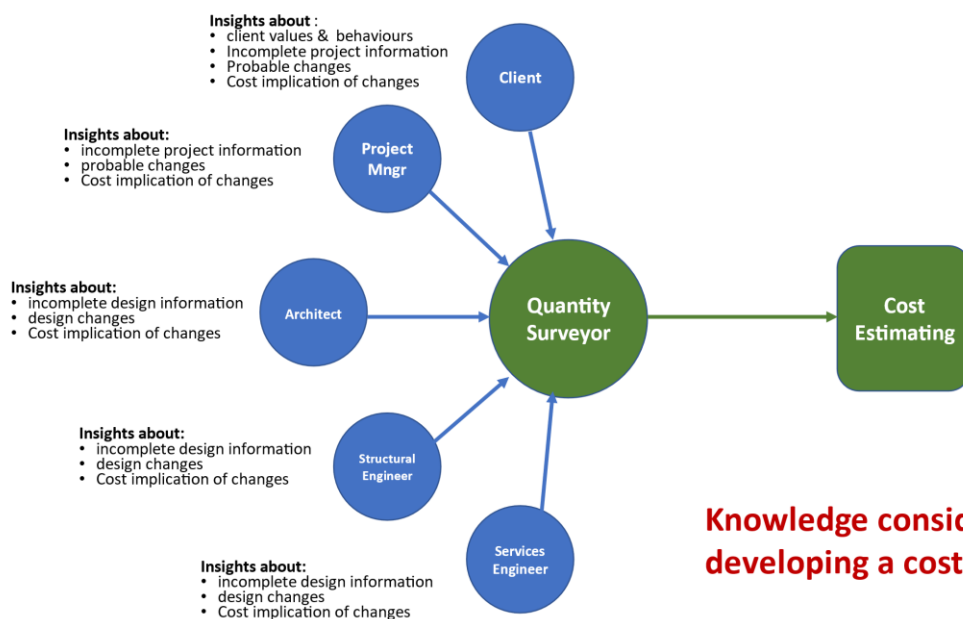
2.3. Information required for cost estimating

Information is the basis upon which estimates are prepared; however, the amount of information needed to prepare an estimate at an early stage is deficient in

projects (Albtoush *et al.*, 2022; Ibrahim & Elshwadfy, 2021). Given that existing cost estimating process models are information-centric, specific information is required when preparing an estimate (DOE, 2016; Bengé, 2018; IPA, 2020). The details/amount of information required is dependent on the type of estimate and when it is prepared (RICS, 2012, 2014; DOE, 2016; Bengé, 2018; IPA, 2020). The NRM1 provides a comprehensive list of information required to prepare a cost estimate, which is an early-stage estimate (RICS, 2012). It specifically outlines 16 types of information from the employer, 11 from the architect, four from the M&E Engineer, and three from the Structural Engineer.

2.4. Knowledge required for improving the accuracy of cost estimates

Since existing Models are information-centric, the only information required for preparing estimates has been captured from the literature. However, to improve the accuracy of estimates, we need much more than information; there is a need to leverage the knowledge and experience of the project team to come up with information where it is not available or not complete. Figure 1 highlights the knowledge considerations for developing a cost estimate.



Knowledge consideration for developing a cost estimate.

Figure 1: Knowledge consideration for developing a cost estimate

2.5. Theories that underpin the Research

Resource-based view requires that organisations focus on the uniqueness of their internal resources to gain organisational efficiency, such as improving the accuracy of estimates (Lewis *et al.*, 2010; Lyons & Brennan, 2019). Systems theory emphasises considering the interrelatedness of various components, engaging in iterative improvement through feedback loops and accounting for the complexities in projects

and hence the cost estimating process (Guan *et al.*, 2020; Ongkowitzo & Doloi, 2018; Boateng, 2017). The contingency theory suggests that there cannot be a "one-size-fits-all" solution. Hence, solutions are situation-specific. To this end, therefore, the dynamic nature of an organisation has to be taken into cognisance (Azman *et al.*, 2020; Bryan & Brennan, 2019).

3. Methodology

The study adopted a two-stage process. At the first stage, articles were identified using the keywords to search from these online databases: Science Direct, Emerald Insight, Google Scholar, Taylor and Francis, and ASCE Library. The keywords were selected from review articles (Albtoush *et al.*, 2021; Chimdi *et al.*, 2020; Hatamleh *et al.*, 2016) on cost estimating related topics, based on the common keywords used by researchers. For this study, the search words include: "Cost Estimating", "Accuracy of cost estimates", "Factors affecting accuracy", "Information required for estimating", etc. Several different variations of the search words were used to collate articles within this domain over a ten year period (2013-2023). Consequently, a total of 115 articles were found and,

more importantly, reduced to 73 articles as a result of systematic refinement to collate articles that are more relevant to the study. Furthermore, these articles were then reviewed to capture details of existing information regarding cost estimating and factors affecting the accuracy of estimates in construction projects, as well as project information used in the selected articles. The following were the inclusion criteria in the selection of articles:

1. Only accessible articles within the following databases: Science Direct, Emeraldinsight, Google Scholar, Taylor and Francis and ASCE library were used
2. Articles selected must focus on cost estimating in the construction industry
3. Articles must have been published between 2013 and 2023
4. Articles must be within the cost estimating process, factors affecting the accuracy of estimates, and theories in cost estimating research.

4.2. Factors affecting the accuracy of cost estimates

out of the 58 aggregated factors revealed across the literature, a critical review showed that 12 relate to knowledge and/or experience relating to either participants or the project (Table 2). These factors were selected to form the basis of developing the conceptual framework, which is the main aim of this research paper, because the focus of this work is on knowledge; it will also be the basis of assessing current cost estimating practices and developing the final process model. The consideration of the factors also provides a significant modification to the existing process models.

Table 2: Factors affecting the accuracy of cost estimates

S/N	Factors Affecting Estimate Accuracy
1	Pricing experience of construction projects
2	Perception of estimation importance
3	Experience and skill level of estimators
4	Certainty of project brief
5	Experience on similar projects
6	Past relationship with clients
7	Level of competition/construction activities
8	Labour cost & performance
9	Number of bidders on competitive projects
10	Stability of market conditions
11	Interest & inflation rate
12	Currency exchange fluctuation

Source: Musarat, et al. (2021); Albtouch et al. (2021); Dandan et al. (2020); Chimdi et al.(2020)

For the exclusion criteria, it has to be "cost estimate", not cost separately and not " estimating separately. It must be for construction projects as well; therefore, the respective bullet points used by the various databases were utilised.

4. Findings and Discussion

4.1. Cost Estimating Process

For the sake of meeting this study's goal, these three industry/organisational documents i.e, from the IPA 8 steps, the GAO 12 steps and the 13 steps NRM 1 process models have carefully been reviewed by identifying and merging similar steps, even if phrased differently, and recognising sub-steps within larger steps to create a unified 10-step model that encompasses the essential elements of cost estimating, drawing from the best practices of various methodologies. The Unified 10 steps have Pre-Preparation Stage (Plan Cost Estimating, Gather Information), Preparation Stage (Gather Data/Evidence, Select Methodology, Compute Base Estimate, Conduct Risk Analysis, Firm up Estimate) and Post-Preparation Stage (Document Estimate, Issue Estimate, Update Estimate).

4.3. Relating Theories to the Study Constructs

The RBV theory suggests that by tapping into the knowledge base inherent within a construction project, improvements in the accuracy of cost estimates can be achieved. That is why the study used the RBV theory and leveraged knowledge. The systems theory explicates the fact that for significant improvement to be made in the accuracy of cost estimates, the consequences of the interaction among the factors, knowledge and the estimating activities must be considered as a whole instead of in isolation. Literature has only been addressing issues of accuracy without examining the process holistically, rather than in isolation. Founded on the contingency theory, the process model to be developed should be able to accommodate project peculiarities. Hence, there would not be any definitive set of factors, knowledge and activities that apply to all projects. Therefore, process requirements are derived based on project characteristics.

4.4. Interrelationship between the study constructs

Intrarelations had been designed between the study constructs, the constructs, theories, and how they relate, as shown in the conceptual framework in Figure 2.

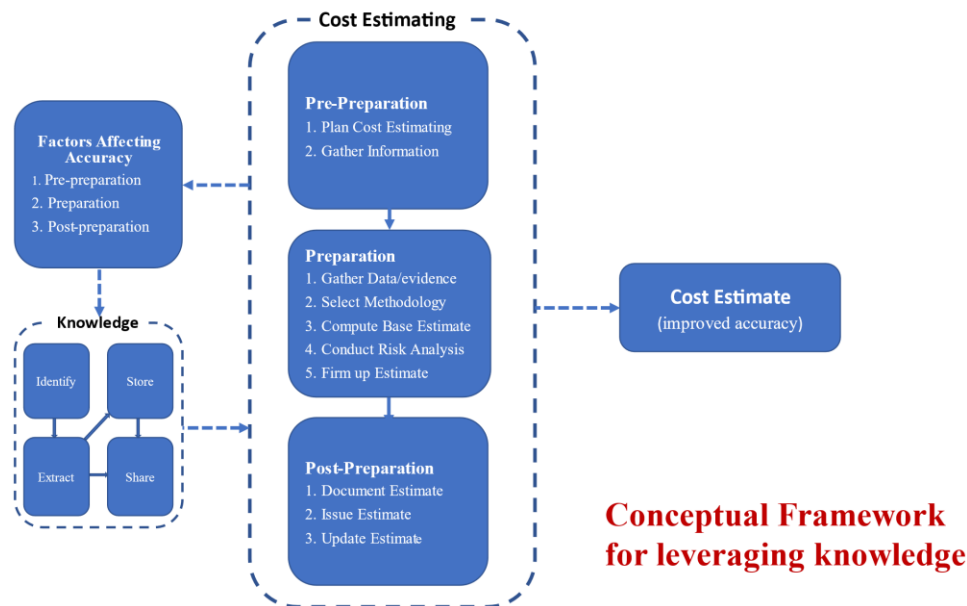


Figure 2: Cost Estimating Conceptual Framework for Leveraging Knowledge

This framework addresses gaps in existing literature by focusing on cost estimating activities, emphasising their iterative and flexible nature, where stages may loop back to previous ones for refinement. It integrates factors affecting estimate accuracy and highlights the importance of knowledge as a unique organisational resource, managed through identification, extraction, storage, and sharing processes. By incorporating the Resource-Based View (RBV) theory, contingency theory, and systems theory, the framework considers knowledge, accuracy factors, and the estimating process holistically, moving beyond reductionist approaches that isolate aspects of estimating. This comprehensive approach aims to improve estimate accuracy by addressing the entire system and process rather than focusing on individual components in isolation.

5. Conclusion and Further Research

The goal was to develop a cost estimating conceptual framework that leverages knowledge in order to achieve the bigger aim of developing a knowledge-based cost estimating process model for construction projects. The study developed the framework and features the various constructs of the research, mainly: Cost estimating Process, factors affecting accuracy of

cost estimates, knowledge required to improve accuracy, all viewed under the theoretical Lens of Resource-Based View theory, Systems theory and contingency theory. The research was conducted mainly using a systematic and critical review of the literature. The developed framework has identified project-specific factors, especially those related to knowledge, that affect the accuracy of cost estimates, thereby bridging the gap between research and practice. It provides a structured approach to cost estimating, which in turn improves the accuracy of estimates. The framework will enhance research rigour, foster advancements in cost estimating methodologies, and inform industry best practices.

The following stages of the research that the researcher will conduct are to operationalise the study constructs to determine the cost estimating practices in Quantity Surveying firms, which will help in developing the as-is model of the research and then determine requirements for leveraging knowledge within the estimating process and finally develop a knowledge-based cost estimating process model for construction projects

References

- Adafin, J., Rotimi, J. O., & Wilkinson, S. (2016). Determining significant risks in the variability between the design-stage elemental cost plan and the final tender sum. *Journal of Management in Engineering*, 32(6), 05016016.
- Akinradewo, O. I., Aigbavboa, C. O., & Oke, A. E. (2020). Improving accuracy of road projects' estimates in the Ghanaian construction industry. *Journal of Financial Management of Property and Construction*, 25(3), 407-421.
- Albtoush, F., Ing, D. S., Rahman, R. A., Al-Btoosh, J. A. A., Albtoush, A. M. F., Doh, S. I., ... & Zaidi, S. M. (2020, December). Factors Affecting the Accuracy of Cost Estimates in Construction

- Projects: A Review. In *Proceedings of the National Conference for Postgraduate Research (NCON-PGR 2020), Virtual Mode* (pp. 1-9).
- Alumbugu, P., Ola-Awo, W., Saidu, I., Abdullahi, M., & Abdulmumin, A. (2014). Assessment of the factors affecting the accuracy of pre-tender cost estimates in Kaduna State, Nigeria.
- Areed, S., Salloum, S. A., & Shaalan, K. (2020). The role of knowledge management processes for enhancing and supporting innovative organisations: a systematic review. *Recent advances in intelligent systems and smart applications*, 143-161.
- Ashworth, A., & Perera, S. (2015). *Cost studies of buildings*. Routledge.
- Benge, D. (2014). *NRM1 cost management handbook*. Routledge.
- Bredehoeft, J. (2012). Modelling Groundwater Flow: Flow-The Beginnings. *Ground Water*, 50(3).
- Chimdi, J., Girma, S., Mosisa, A., & Mitiku, D. (2020). Assessment of factors affecting the accuracy of cost estimation in public building construction projects in the Western Oromia region, Ethiopia. *Journal of Civil Engineering, Science and Technology*, 11(2), 111-124.
- Dandan, T. H., Sweis, G., Sukkari, L. S., & Sweis, R. J. (2020). Factors affecting the accuracy of cost estimate during various design stages. *Journal of Engineering, Design and Technology*, 18(4), 787-819.
- Egboga, I., Daniel, C. O., & Abubakar, H. L. (2022). Effect of Cost Estimation on Project Performance in Construction Firms in Abuja. *Turkish Online Journal of Qualitative Inquiry*, 13(1).
- Enshassi, A., Mohamed, S., & Abdel-Hadi, M. (2013). Factors affecting the accuracy of pre-tender cost estimates in the Gaza Strip. *Journal of Construction in Developing Countries*, 18(1), 73.
- Hardash, J. A., & McGurk, S. (2008, March). Credible Space Cost Estimating Policy for NASA: Making Sensible Requirements Work. In *2008 IEEE Aerospace Conference* (pp. 1-9). IEEE.
- Hatamleh, M. T., Hiyassat, M., Sweis, G. J., & Sweis, R. J. (2018). Factors affecting the accuracy of cost estimate: case of Jordan. *Engineering, Construction and Architectural Management*, 25(1), 113-131.
- Ibrahim, A. H., & Elshwadfy, L. M. (2021). Factors affecting the accuracy of construction project cost estimation in Egypt. *Jordan Journal of Civil Engineering*, 15(3).
- Jiang, Q. (2020). Estimation of construction project building cost by back-propagation neural network. *Journal of Engineering, Design and Technology*, 18(3), 601-609.
- Khodabakhshian, A., & Toosi, H. (2021). Residential real estate valuation framework based on life cycle cost by building information modeling. *Journal of Architectural Engineering*, 27(3), 04021020.
- Kirkham, J. J., Gorst, S., Altman, D. G., Blazeby, J., Clarke, M., Devane, D., ... & COS-STAR Group. (2015). COS-STAR: a reporting guideline for studies developing core outcome sets (protocol). *Trials*, 16, 1-6.
- Kumar, A., & Patro, B. D. K. (2021, October). Modelling and representation of software framework cost estimation using convolutional neural networks. In *2021, the 5th International Conference on Information Systems and Computer Networks (ISCON)* (pp. 1-5). IEEE.
- Moore, S. (2020). *RICS professional education and training for quantity surveyors, and the extent to which it is relevant in the current UK built environment market*—University of Salford (United Kingdom).
- Musarat, M. A., Alaloul, W. S., & Liew, M. S. (2021). Impact of inflation rate on construction projects budget: A review. *Ain Shams Engineering Journal*, 12(1), 407-414.
- Ning, F., Shi, Y., Cai, M., Xu, W., & Zhang, X. (2020). Manufacturing cost estimation based on a deep-learning method. *Journal of Manufacturing Systems*, 54, 186-195.
- Sayed, M., Abdel-Hamid, M., & El-Dash, K. (2023). Improving cost estimation in construction projects. *International Journal of Construction Management*, 23(1), 135-143.
- Tayefeh Hashemi, S., Ebadati, O. M., & Kaur, H. (2020). Cost estimation and prediction in construction projects: A systematic review on machine learning techniques. *SN Applied Sciences*, 2(10), 1703.

- Trost, S. M., & Oberlender, G. D. (2003). Predicting accuracy of early cost estimates using factor analysis and multivariate regression. *Journal of Construction Engineering and Management*, 129(2), 198-204.
- Wang, R., Asghari, V., Cheung, C. M., Hsu, S. C., & Lee, C. J. (2022). Assessing effects of economic factors on construction cost estimation using deep neural networks. *Automation in Construction*, 134, 104080.

Appendix 1**Table 1:** Factors affecting the accuracy of cost estimates

S/N	Factors affecting the accuracy of cost estimates
1	Pricing experience of construction projects
2	Perception of estimation importance
3	Equipment (cost/availability/performance)
4	Clear scope definition
5	Site constraints (access, storage, services)
6	Financial capabilities of the client
7	Availability of a database of bids on similar projects (historical data).
8	Clear and detailed drawings, specifications and project documentation.
9	Experience and skill level of estimators.
10	Completeness of cost information, accuracy, reliability, quality and details
11	Materials (prices, availability, quality, imports).
12	Experience on a similar project.
13	Accuracy of BOQ.
14	Management team (suitability, experience, performance
15	Quality of assumptions used in preparing the estimate
16	Complexity of design and construction
17	Build ability
18	Scale and scope of construction
19	Construction techniques
20	Construction location (regions / rural; urban)
21	Project duration
22	Certainty of project brief
23	Client requirements on quality
24	Type of client (public/private)
25	Experience on similar projects
26	Past relationship with clients
27	Current workload
28	Need for work
29	Planning capability
30	Absence of alterations and late change
31	Procurement method
32	Type of contract
33	Tendering method
34	Variation order
35	Level of competition and Level of construction activity
36	Material cost
37	Labour cost /performance
38	Number of bidders on competitive projects
39	Stability of market conditions
40	Interest rate/inflation rate

41	Poor tender document
42	Insufficient estimating time
43	Insufficient analysis of the tender document
44	Shortage of project requirements.
45	Basis of selection (open, selective and direct negotiation).
46	Commitment of the client to the project.
47	Project technology and complexity level.
48	Ability of quantity surveyors to cope with stress (work pressure).
49	Communication barrier.
50	Familiarity of quantity surveyor with the type of projects.
51	Perception of estimating importance.
52	Expected level of error in estimates.
53	Limited time to prepare the estimate due to the deadline.
54	Estimating method used in the preparation of estimates.
55	Organisation's estimating procedure
56	Border closure and blockade.
57	Currency exchange fluctuation.
58	Clear contract conditions.

Source: Musarat, et al. (2021); Albtoush et al. (2021); Dandan et al. (2020); Chimdi et al. (2020)