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Cost estimation: Strategic formulation based on affecting factors in government infrastructure

Djoko Subagijo[1,2*], Imam Wahyudi[2], Jujuk Kusumawati[1]

[1]*Civil Engineering Study Program of Institut Teknologi Budi Utomo, Jakarta, Indonesia.*
[2]*Departmenet of Civil Engineering of Universitas Islam Sultan Agung, Semarang, Central Java, Indonesia.*

Corresponding author: Djoko Subagijo (*Email: djokos@itbu.co.id*)

Abstract

Cost Estimation is an important part of infrastructure planning; errors in cost estimation will have an impact on infrastructure that does not achieve the project's performance in terms of cost, quality, time, safety, and environmental sustainability. This study aims to develop a strategy based on factors that are considered to influence cost estimates in government infrastructure. Using a mixed-methods approach (quantitative and qualitative analysis), this study will develop a strategy formulation that can be recommended to stakeholders. Quantitative analysis is conducted by distributing questionnaires and then performing statistical tests to identify factors that are considered to influence the cost estimation of government infrastructure. Qualitative analysis is conducted through focus group discussions (FGDs) to validate the results of the quantitative analysis. The cost estimation model in this study will provide recommendations for preparing sustainable strategies in government infrastructure, in line with technological advancements. Accurate cost estimation will help government budget efficiency activities in the optimal use of state funds to achieve development goals with maximum results and positive impacts on society, and optimising the use of financial resources to reduce waste, increase productivity, and ensure that each budget has a significant impact on infrastructure development and provides added value.

Keywords: Cost efficiency, Cost estimation, Government infrastructure, Infrastructure, Strategic formulation.

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1. Introduction

Government infrastructure has an impact on improving the country's economy. The existence of infrastructure is fundamental to ensure the availability of facilities and infrastructure to carry out strategic activities in a country. In the development of government infrastructure, cost estimates are crucial to ensure the state budget is utilised effectively. The allocation of infrastructure budget in Indonesia, which reaches above 10% [1, 2] must be balanced with professional practices, one of which is accuracy in carrying out conceptual cost estimates before the project begins [3-6]. Accurate cost estimates will prevent additional work and cost overruns from occurring on the project; instead, they will ensure the project has high performance and is delivered on time Amade and Akpan [7] and Bayram and Al-Jibouri [8]. Fazil, et al. [9] state that six dimensions influence the accuracy and efficiency of cost estimation, including input control, behaviour control, output control, task characteristics, technology characteristics, and project complexity. These six factors, if fulfilled in the cost estimation aspect, will create high and timely project performance.

The development of government infrastructure in Indonesia presents a classic problem, characterised by inaccuracy in cost estimates prepared at the initial (conceptual) stage. Historical price-based bidding methods are frequently employed to develop designs [10]. This method can be used in cases where the details of historical bid data are not fully available. In Indonesia itself, the estimates show a level of inaccuracy in road projects of (-) 25.21% to (+) 26.84%, and in building projects, ranging from (-) 12.97% to (+) 26.80% [10].

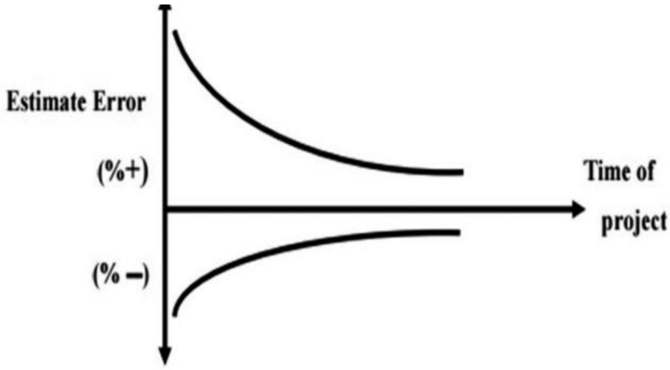

Figure 1.
Relationship between time and estimate errors.
Source: Dandan, et al. [11].

Figure 1 above illustrates the relationship between cost estimation errors and project implementation time. Error estimation causes the project implementation time to increase. This figure shows the low accuracy of infrastructure cost estimation in Indonesia. Inaccurate cost estimation results in the optimisation of the infrastructure budget not being appropriately realised, often causing a reduction in building functions, facilities, and infrastructure, including site development. Optimising the cost of building construction work risks reducing the quantity of work items required for technical specifications, and consultant fees are also a factor that influences cost estimates [12, 13]. Limitations of specificity of Cost Estimation Parameters the current conceptual stage cost estimation based on area volume, standard and non-standard costs, classification, building type, building height, and site development is still considered less specific, as a result, it is not yet known for sure which parameters significantly affect the accuracy of cost estimation at the conceptual stage.

Inaccuracy in cost estimates creates risks, including requirements such as building and environmental layout, building materials, building structures, utilities, infrastructure, facilities in buildings, safety facilities, reduced space requirements, reduced building material specifications, levels of security and comfort, building maintenance, building sustainability, and other needs [10, 12, 14, 15]. Other problems that arise during construction implementation also have an impact, for example, delays in land handover (site acquisition), the asset disposal process which takes a relatively long time, field limitations, changes in space function (space program/organisation), design changes, the emergence of additional and less work, and so on [16-18]. The agencies at both national and regional levels require special consultation with the Cipta Karya board and the Ministry of Public Works and Housing. This process is based on existing regulations [19] with added experience, imagination, and various assumptions from the estimator, including assessments of previous projects with a similar scope [10, 20].

This study aims to compile factors that are considered to influence the parameters in conducting technology-based cost estimation. Accurate cost estimation preparation will have an impact on various aspects, including determining tender cost estimates, reducing the time required to compile cost estimates, updating cost information, ensuring the availability of clear indicators, enhancing estimator experience, improving accuracy in determining costs according to the planned building area, and increasing Human resources' competence [15].

2. Theoretical Literature Review

2.1. Cost Estimation

Cost estimation is a crucial element for the success of a construction project. Accurate estimation allows for contract optimisation and involves a comprehensive calculation of all costs associated with a project. This process occurs before construction begins and even before the project is tendered. Construction cost estimation is the process of estimating the cost of a building as a physical structure [21, 22]. Estimation is defined as a technical process for estimating the cost of implementing activities to achieve the stated objectives of a construction project within a specified period. The estimate must be accurate and must be based on detailed project information. Cost estimation is defined as a predictive process that measures financial resources, depending on the scope of investment, to determine the project budget [6].

Cost estimates performed at the start of a project provide the basis for decisions about whether to continue the project. At later stages, cost estimates allow for the monitoring of project progress and inform decisions about completing or terminating the project [6]. The challenge for QS is to produce estimates that accurately reflect reality. Cost estimating involves the collection, analysis, and summarisation of data available for a construction project, considering the specific elements of labour, materials, and plant unit costs for each item of work as outlined in the bill of quantities and job specifications Amade and Akpan [7]. Enhassi, et al. [23] and Amade and Akpan [7] argued that estimation is an important and key step in the construction process because its reliability, in terms of accuracy, from the conceptual stage to the final stage, determines the success or failure of a project. Ashworth [24] and Amade and Akpan [7] identified types of cost estimates, including preliminary, feasibility, viability, authorisation, final budget, and control. Some factors that contribute to inaccuracy in cost estimation include the increase in imported materials, the experience of the project estimator team, project land closure, project size, owner capability, project type, project location, market conditions, site constraints, and work methods [7]. Project cost estimation is critical to the success of a project and should be considered from the early stages of the project; otherwise, poor estimation can lead to project failure, in terms of time, cost or even in the opinion of stakeholders [6]. There are five main factors in estimating construction costs:

1. Cost Estimator (QS) [3, 4]**:** Refers to the artistic ability to estimate the costs required for an activity based on available information.
2. Current Data [22]**:** Current data collected within the relevant time frame (less than 180 days) before being converted into electronic format.
3. Project Information [8]**:** Covers data and documentation generated from various sources throughout the project (engineering, vendors, contractors, Commissioning & Qualification team). Accurate and complete information is essential for the project team and the owner**.**
4. Historical Data [21]**:** Data collected from relevant past events and conditions, including financial statements, project documentation, and communications. This data serves as a basis for comparison and future projects [21, 22].
5. Estimating Methodology [25, 26]**:**

- Comparison/analogy
- Parametric
- Detailed/bottom-up engineering
- Extrapolation from actual costs

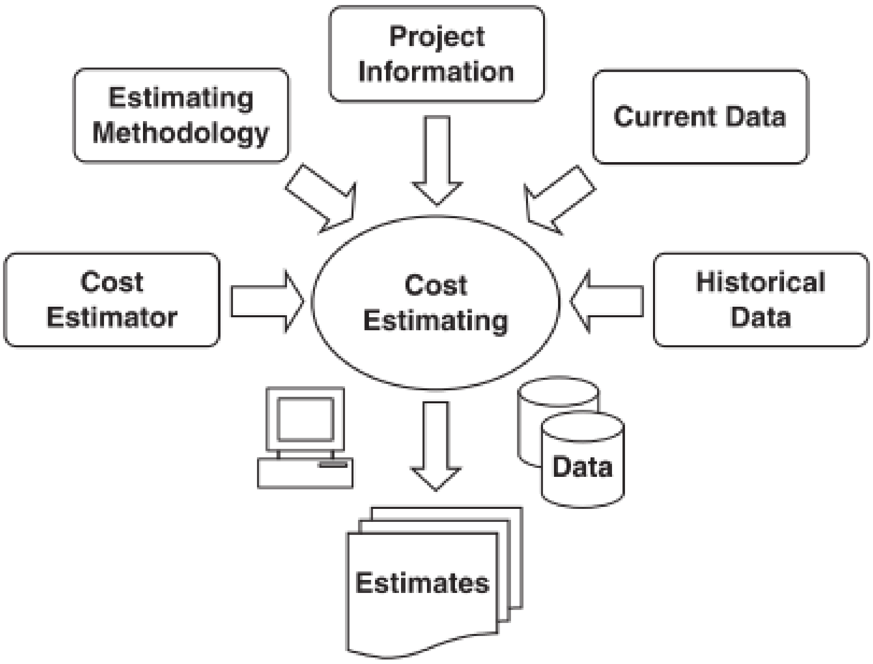

Figure 2.
Main factor cost estimation.
Source: Kim, et al. [25].

Figure 2 above illustrates that the key components in compiling cost estimates are influenced by the estimating methodology, project information, cost estimator, current data and historical data [25].

2.2. Government Infrastructure

According to the Regulation of the Minister of Public Works and Public Housing (PUPR) Number 22 of 2018, "State Buildings" or "Government Buildings" refer to buildings designated for public interest that are owned by the state or region and financed through government funding [27, 28]. The construction of Government buildings is the activity of constructing buildings which is carried out through the stages of technical planning, construction implementation, and supervision, whether it is new construction, building maintenance, or expansion of existing buildings, and/or continued construction of buildings [29].

The construction of state buildings encompasses the activities of building construction through the stages of technical planning, implementation, and supervision [30, 31]. This includes new construction, building maintenance, expansion of existing buildings, and/or additions to existing buildings. The government's building guidelines cover several important aspects:

2.2.1. Administrative Requirements, Including

- Land rights status and/or utilisation permit from the land rights holder.
- Building ownership status.
- Building Permit.
- Other supporting documents such as Funding Documents, Planning Documents, Construction Documents, and Registration Documents.

2.2.2. Technical Requirements, Including

- Building Layout: Designation of location and intensity of building construction; Building architecture; Environmental impact control; Building and Environmental Layout Plan; Construction of buildings above and/or below land, water, and/or public infrastructure/facilities.
- Building Reliability, including several requirements: Safety; Health; Comfort; and Convenience.

The Construction Cost Components include:

- Construction Implementation Costs: These costs are charged to the physical construction components of the activity, consisting of: Standard Costs and Non-Standard Costs calculated based on the type of work, real needs, and fair market prices. The total non-standard costs are capped at 150% of the total standard costs.
- Technical Planning Costs: Technical planning costs are charged to the Construction Planning activity components and paid in stages: Design Conception Stage: 10%; Pre-Design Stage: 20%; Design Development Stage: 25%; Detailed Design and Budget Plan Stage 25%; Construction service provider auction stage: 5%; and Periodic Supervision Stage: 15%
- Technical Supervision/Construction Management Costs: There are two types of supervision activities according to building classification: Technical Supervision Activities: For simple/non-simple classifications, charged to the cost of the technical supervision activity components and paid in stages and Construction Management Activities: For non-simple/special building classifications, charged to the cost of the construction management activity components and paid in stages.
- Activity Management Costs: These costs are allocated for Technical Management activities, as the provision of technical assistance by the Minister to Ministries/Agencies using the Budget/Goods.

2.2.3. Unit Cost Standard

The unit cost standard is the maximum price set for building construction work, serving as a guideline to ensure the transparency and efficiency of public budget spending. The unit cost must be updated and determined periodically, annually, by authorised officials within the hierarchy. A unit cost standard is needed for calculating the cost of implementing physical construction, including the Building Approval Fee, Building maintenance costs, and Current asset value (present value) [12, 32, 33].

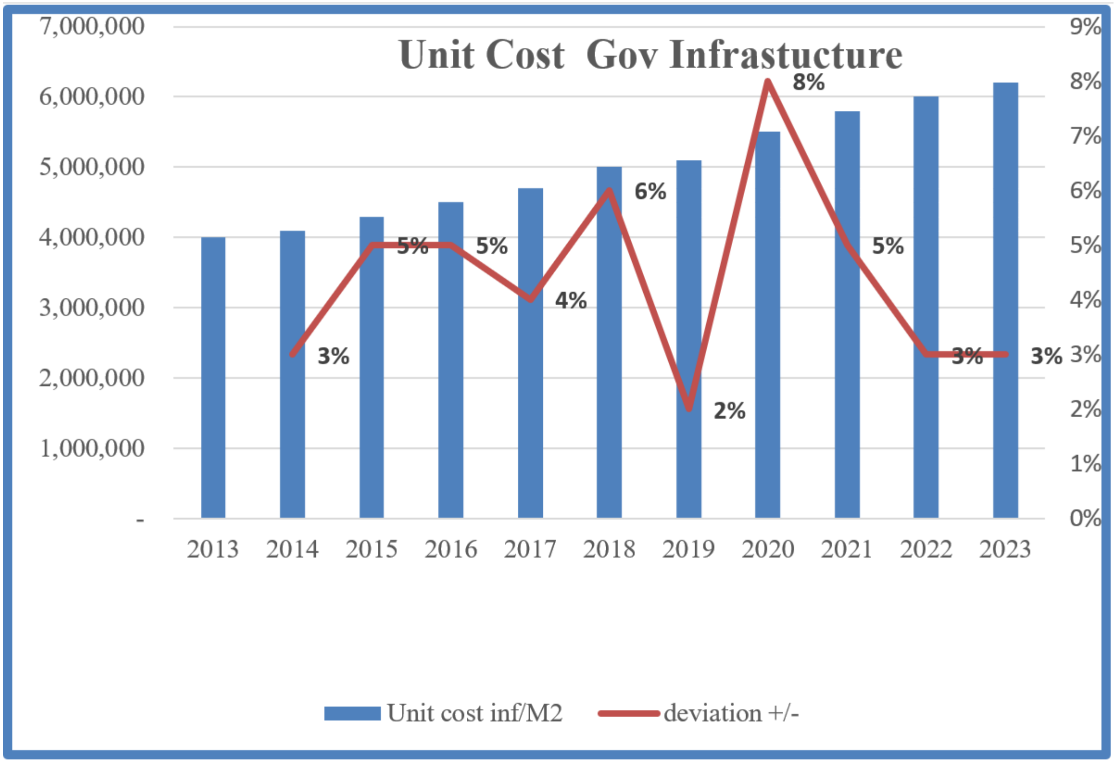

Figure 3.
Progress unit cost of government Infrastructure in Indonesia.

Figure 3 above shows the standard unit cost for government infrastructure development in Indonesia, which is used for implementing standard physical construction, including architectural work, structure, utilities, such as plumbing work, lighting installation networks, and finishing. Standard costs include construction overhead, insurance, work safety, inflation, and taxes, as mandated by laws and regulations.

3. Materials and Methods

This study uses a mixed method consisting of quantitative and qualitative analysis [34-38]. Quantitative analysis aims to explore perceptions related to factors that are considered important in influencing the accuracy of cost estimation. This quantitative analysis was conducted with 40 respondents who met directly to complete the questionnaire. Furthermore, the results of the questionnaire were analysed using SPSS; the result is a model that is recommended as a strategy in compiling technology-based cost estimates [36-38]. The next stage involves conducting a qualitative analysis through a focus group discussion (FGD) with experts to validate the research results. This validation employs the Delphi method [39-41] to establish a consensus on the model that will be recommended as a strategy for compiling technology-based cost estimates [42-44]. The number of experts involved in the FGD was 15 experts, consisting of:

Table 1.
List of experts.

Respondent	Actors	Position/role
1	Owner	Government/PUPR
2		Government/PUPR
3		Head of Government Estimator
4		Head of Government Estimator
5		Government Estimator
6	Contractors	Project Manager
7		Senior Project Manager
8		Operational Manager
9		Head of Estimator
10	Designer	Senior designer
11		Senior designer
12	Academic	Professor of Project Management
13		PhD in Project Management
14		PhD in Project Management
15		PhD in Project Management

The results of the qualitative analysis aim to validate the model developed in the questionnaire, assessing its suitability and providing recommendations that can be applied to prepare cost estimation at the conceptual stage. The details of the steps in this study are as described in the following chart:

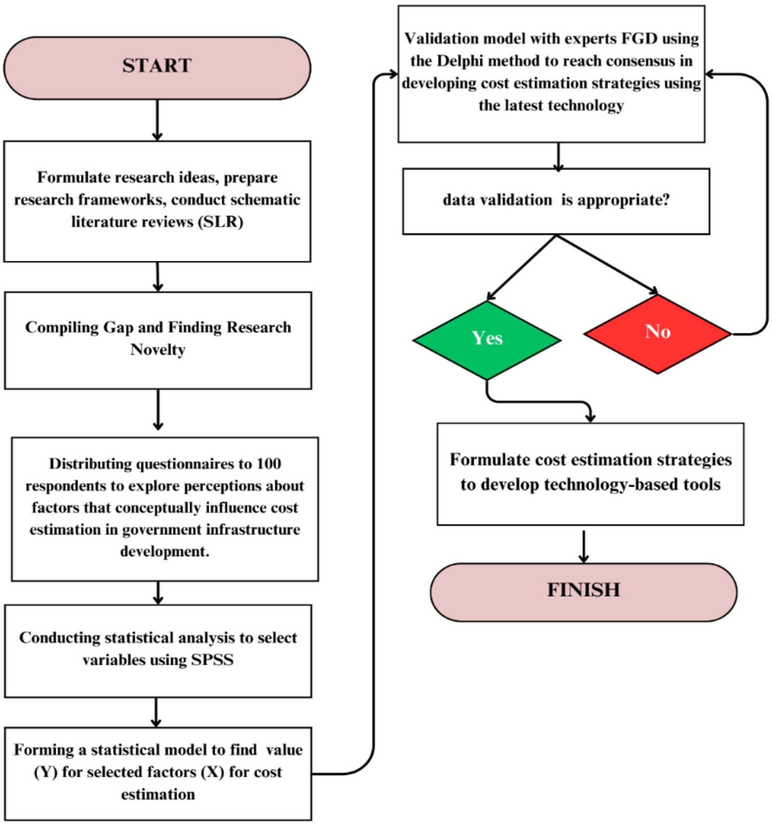

Figure 4.
Research Methodology.

Figure 4 above illustrates the research methodology employed in this study, which involved a preliminary questionnaire test conducted on the first 40 respondents, followed by a larger-scale test on a sample of 40 respondents. The analysis was conducted using a mixed-methods approach (qualitative and quantitative) to develop an appropriate model that can be recommended for the strategic formulation of cost estimation based on factors affecting software development. The profile of respondents in this study is as follows:

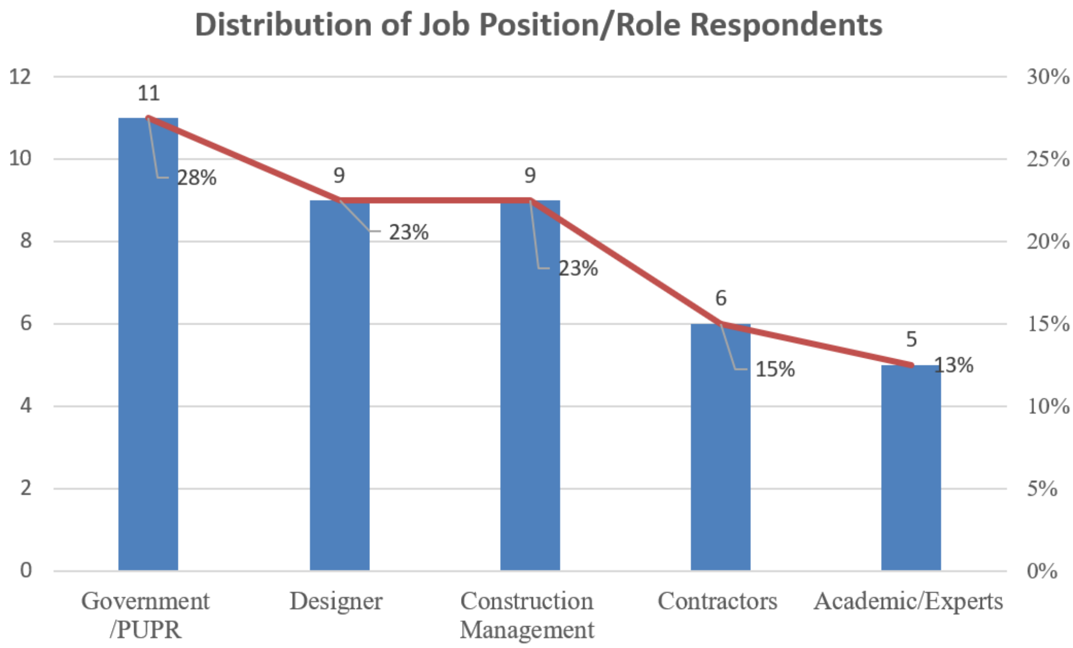

Figure 5.
Distribution of job positions/roles respondents.

Figure 5 The above shows that respondents came from five sources: government ministries and sub-ministries (28%), designers (23%), construction Management (23%), contractors (15%), and academics/experts (13%). The largest respondents came from the government, as this study aimed to assess the perspective on cost estimation at the conceptual phase that would be used in the tender document. In comparison, other respondents will strengthen the impact of the factors to be studied later in the design phase and project implementation.

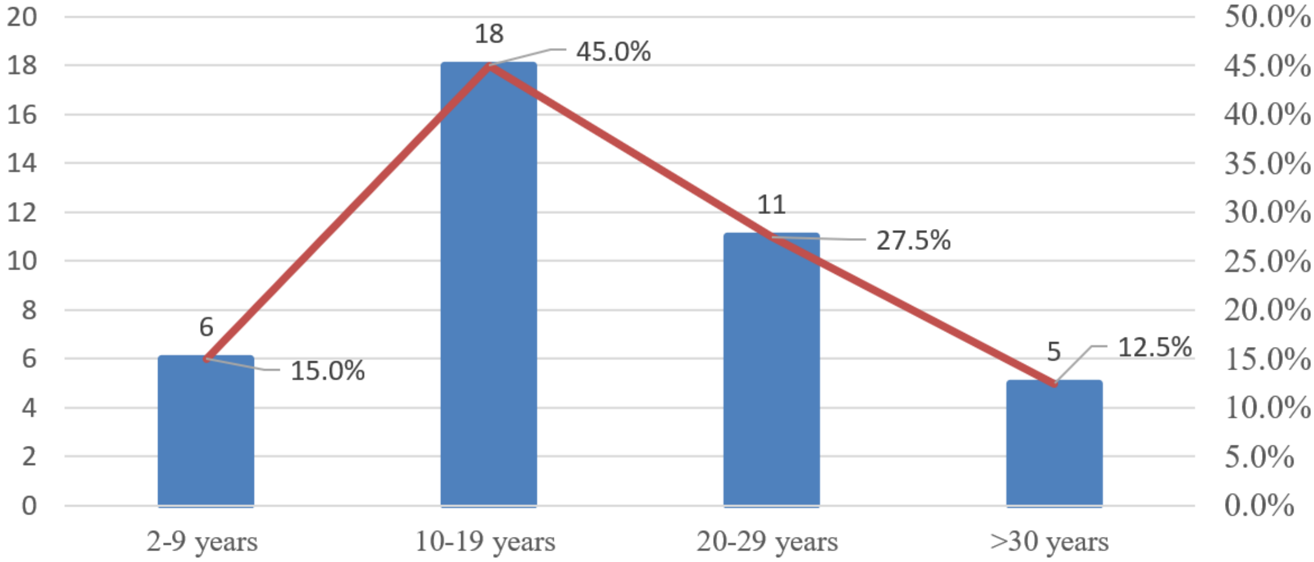

Figure 6.
Distribution of job experience respondents.

Figure 6 The above illustrates the distribution of work experience among respondents, where respondents with 10-19 years of work experience dominate up to 45%. This means that the questionnaire in this study was administered to respondents who had sufficient experience in cost estimation and government projects, thereby minimising bias caused by respondents' unfamiliarity with the questionnaire. Their perceptions are important because they will serve as the basis for compiling a strategy for formulating government project cost estimation, incorporating technological developments.

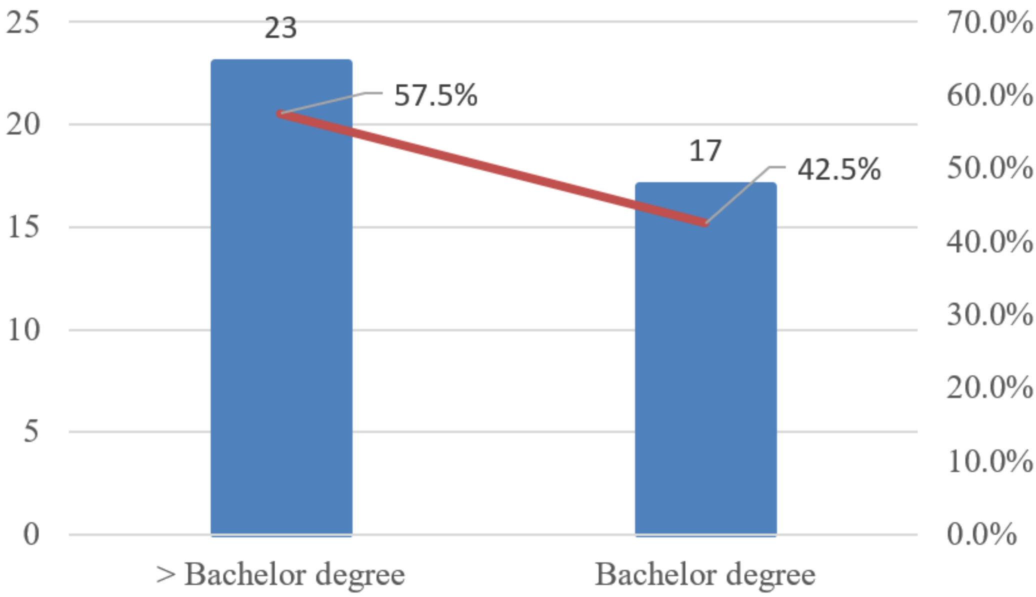

Figure 7.
Distribution of education respondents.

Figure 7 above describes the distribution of educational respondents who hold a bachelor's degree and higher, indicating that this research takes into account the knowledge possessed by the respondents, not just their work experience.

4. Results

4.1. Quantitative Analysis

Quantitative testing is conducted using SPSS, which aims to perform reliability tests on variables. The first reliability test is done by finding the alpha value. If the alpha value is greater than 0.6, this indicates sufficient reliability. If the alpha value is greater than 0.80, this suggests that all items are reliable and all tests consistently demonstrate strong reliability. If alpha is greater than 0.9, then the reliability is perfect; if alpha is between 0.70 and 0.90, then the reliability is high. If alpha is 0.50 - 0.70, then the reliability is moderate. If alpha < 0.50, then the reliability is low. If alpha is low, it is likely that one or more items are not reliable [45, 46].

Conbrach Alpha value = (1- (item variance/total variance))
K = number of questions
Item variance value = 158.46
Total variance value = 8018
K/K-1 = 1,048
Item variance/total variance = 0.02

Conbrach Alpha value = 1.027, meaning the value > 0.6 is declared Reliable.

The following analysis aims to determine the correlation between each variable. This analysis aims to measure the relationship between all independent variables, which are evaluation factors in the conceptual cost estimation stage. Independent variables (X) with a value of $r \geq 0.1$ are considered to have a close relationship and will be further analysed using RII (relative Importance Index). In the analysis of 40 respondents, a relatively high RII value was obtained. There are eight key variables, namely the level of complexity and/or technology (X3.1), Type and Function of Building (X4.1), Floor Area (X1.1), Deep Foundation Work (X2.16), Floor Height Coefficient (X5.2), Main Room (X6.1), Green Building Cost Coefficient (X7.1) and Cut and Fill/Earthwork (X8.1). The RII values of the eight factors are as follows:

Table 2.
Tabulation variable.

Variable	RII	Coefficient
Intercept		0.715
X3.1	0.94	0.229
X4.1	0.90	0.240
X1.1	0.93	0.182
X2.16	0.85	0.131
X5.2	0.91	0.295
X6.1	0.95	0.042
X7.1	0.92	0.141
X8.1	0.90	0.095

The eight variables have a t-statistic value that is positive, indicating a good fit with the following causal model equation.:

Y=0,725+0,229(X3.1) +0,240(X4.1) +0,182(X1.1) +0,131(X2.16) +0,295(X5.2) +0,042(X6.1) +0,141(X7.1) +0,095(X8.1)

Factors such as X5.2 (0.295), X4.1 (0.240), X3.1 (0.229), and X1.1 (0.182) exhibit a relatively greater influence than the others. Overall, this model indicates that the combination of these factors significantly and positively contributes to the accuracy of conceptual stage cost estimation.

4.2. Qualitative Analysis

Qualitative analysis was conducted through an expert FGD involving 15 experts. In this FGD, the Delphi method was used for consensus [41, 47] which was conducted in 2 stages:

Stage 1: Each expert is given time to provide feedback on the resulting model, which consists of eight dimensions. Each expert can agree to add or remove variables in each dimension, as well as moderate variables or introduce new ones if necessary, to expand the discussion.

Stage 2: Experts provide weighting and consensus on the selected factors, offering a brief discussion as needed.

From the qualitative analysis through FGD, several conclusions were produced as follows:

Government: These factors are considered important such as the level of complexity and/or technology (X3.1), Type and Function of Building Structure (X4.1), Floor Area (X1.1), Deep Foundation Work (X2.16), Floor Height Coefficient (X5.2), Main Room (X6.1), Green Building Cost Coefficient (X7.1) and Cut and Fill/Earthwork (X8.1), it is necessary to add regulations and historical data as an addition in conducting cost estimation. In the regulation, input data can be in the form of technical requirements that are not included in the eight variables. Historical data can be used as benchmarks and to establish lower and upper limits for determining the unit price of the work.

Designer: The most important factor that designers consider when compiling cost estimates is the type of building, which determines the criteria for selecting building materials. The green building coefficient is a crucial reference in design because it varies by building type. Designers will consider sustainability and ESG as important factors in design, therefore important ESG factors are included in cost estimates such as the amount of use of environmentally friendly materials, energy consumption and social aspects such as stakeholder equality in the project, and the type of project delivery used because it will affect the design cost.

Contractor: operational aspects in cost estimation are building function, main space, cut and fill. These three factors have a significant impact on project implementation, so the estimated cost must be accurate. Other factors have an effect in a lower gradation, but are still considered influential. The project delivery system model needs to be considered because it anticipates the increase in material prices during the implementation of the work, as the cost estimate is prepared 1-2 years prior to the project's implementation. In addition to accurate cost estimates, effective owner communication with stakeholders is crucial to anticipate potential rising interest rates. Interest rates are among the factors used to design cost estimates.

Academic: The project delivery system will significantly affect the cost estimate to be implemented, so the project delivery system factor must be included in the planning of the cost estimation system to be built. The defined factors should be added to the estimator qualification as an important factor, with a minimum competence proven by a certificate. Interest rates are also an important consideration, as infrastructure development often relies on funds from third parties, not just government funds.

5. Discussion

Quantitative analysis was conducted with attention to Cronbach's alpha values above 0.7 [45, 46, 48] where the value indicates high validity and reliability in statistics. The statistical test using SPSS in this study shows that the variables considered to influence cost estimation have a Cronbach's alpha value above 0.7. The variables considered to have a high correlation consist of 8 variables, namely the level of complexity and/or technology (X3.1), Type and Function of Building (X4.1), Floor Area (X1.1), Deep Foundation Work (X2.16), Floor Height Coefficient (X5.2), Main Room (X6.1), Green Building Cost Coefficient (X7.1) and Cut and Fill/Earthwork (X8.1). In the FGD, experts proposed several things such as regulations, historical data, ESG sustainability, project delivery system [49-51] partnering and communication between stakeholder [52-56] and interest rate. This is in line with what was conveyed by Kim, et al. [25] that in estimating costs, consider historical data: the cost data for historical projects and their building characteristics, Current data: the unit costs and rates (for material, labor, and equipment), historical cost indices, and other items., estimating methodology: the method used for the estimation, including singleunit rate methods, parametric cost modeling methods, and system/elemental cost analysis, Cost estimator: the user who employs all the other elements in making an estimate and applying judgments during the estimating process.

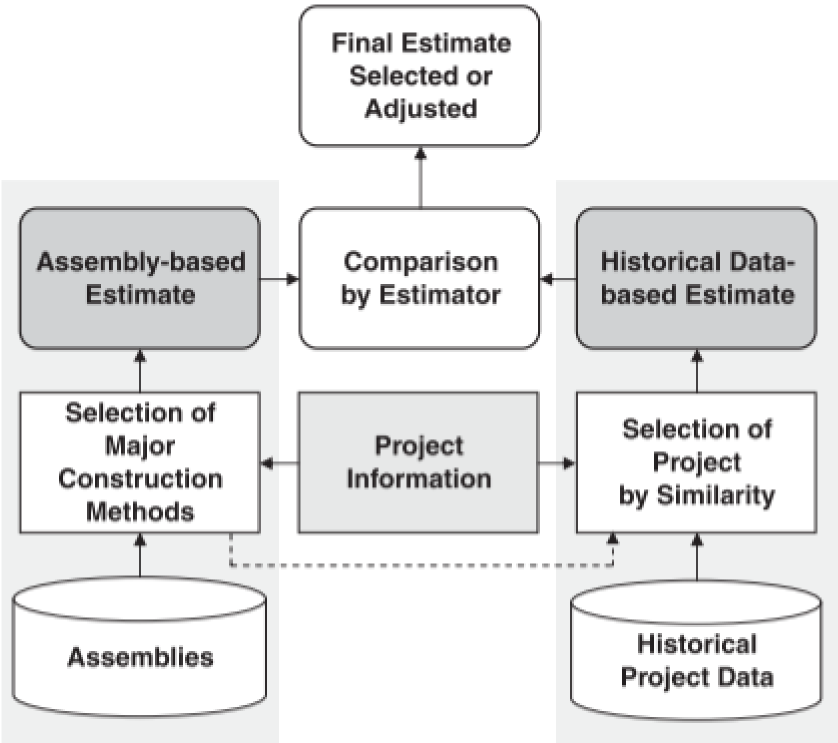

Figure 8.
Cost estimation hybrid.
Source: Kim, et al. [25].

Kim, et al. [25] propose a hybrid method for cost estimation to produce more accurate cost estimates through selection and judgment.

Samarasekara, et al. [57] states that to estimate the cost must consider several factors including: Estimated annual occupancy hours and building type/functionality, Construction technology and building type/functionality, Variations in various costs and risk allowances, Variations in various costs, level of uncertainty and risk allowances, Government regulations, taxation, rate of interest and foreign exchange. This is very much by the quantitative and qualitative analysis found in this study, so that the findings in this study can be described in the following model:

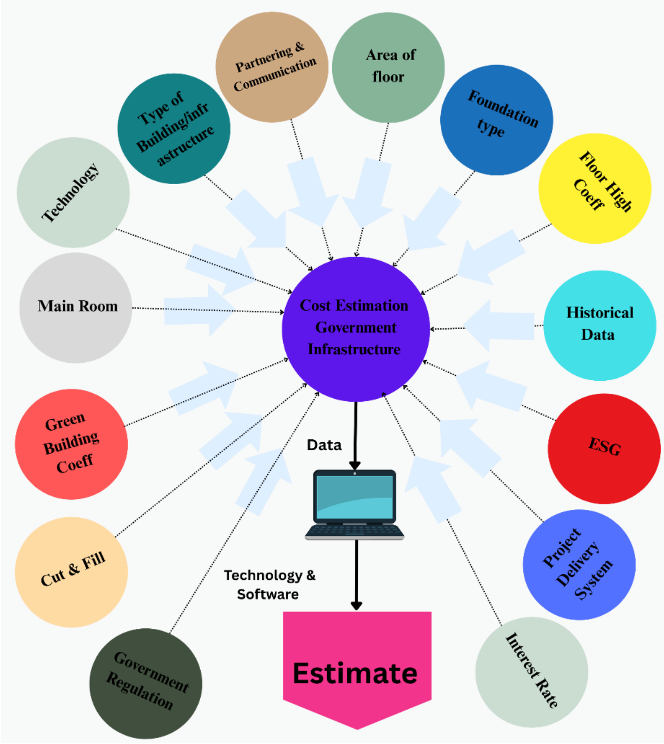

Figure 8.
Model cost estimation.

Figure 8 above is a cost estimation model that can be recommended for developing a strategy to consider influential factors and key variables in technology-based input cost estimation for government infrastructure.

6. Conclusions

From the research results above, the following can be concluded:

1. When conducting cost estimation for government infrastructure development, it is necessary to analyse the factors that influence it. In this study, 14 factors were found that can be used as considerations in conducting cost estimation in government infrastructure development consisting of Level of complexity and/or technology, Type and Function of Building, Floor Area, Deep Foundation Work, Floor Height Coefficient, Main Room, Green Building Cost Coefficient, Cut and Fill/Earthwork, regulations, historical data, ESG sustainability, project delivery system, partnering and communication between stakeholders and interest rate.
2. To implement the cost estimation method using technology, quantitative indicators must be identified as coefficients. These quantitative indicators can be from SPSS data processing coefficients and the use of binary scales for other indicators, such as project delivery systems, and the level of partnering between stakeholders. In comparison, indicators for ESG and interest rates can be entered in the form of maximum or minimum target inputs.
3. This recommendation is intended for submission to the government, which is conducting cost estimation during the conceptual phase of developing government infrastructure.

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