

Relationship Model Between Cost Estimation Process Risk and Cost Accuracy on Green Neighborhood Projects: A Case Study of Jogja Planning Gallery

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ABSTRACT : *Cost accuracy in green neighborhood projects is a critical factor in ensuring sustainable project delivery. However, the cost estimation process is inherently exposed to various risks that can lead to significant deviations in project budgets. This study aims to develop a relationship model between cost estimation process risks and cost accuracy in green neighborhood projects, using the Jogja Planning Gallery (JPG) project as a case study. Data were collected through a questionnaire survey of 40 respondents consisting of practitioners with expertise in cost estimation and project management. Statistical analyses including homogeneity tests, validity and reliability tests, correlation analysis, factor analysis, and stepwise multiple linear regression were conducted using SPSS version 27. Results show that from 45 identified risks, 33 were classified as high-level risks, which were then grouped into 8 risk categories (X1–X8). Regression analysis revealed that the risk category of Tender Document Preparation and Budget Approval (X8) is the most dominant factor influencing all five cost accuracy indicators (Y1–Y5). The regression models produced Adjusted R² values ranging from 48.2% to 53.0%. These findings indicate that errors in document preparation—including unit price determination, estimator comprehension of project scope and execution methods, and calculation inaccuracies—significantly reduce cost accuracy. The developed models provide practical tools for improving cost estimation reliability in green neighborhood construction projects.*

KEYWORDS - *cost accuracy, cost estimation, green neighborhood, regression model, risk analysis*

I. INTRODUCTION

The construction industry is one of the largest contributors to global carbon emissions, energy consumption, and resource depletion. In response to increasing environmental concerns, green neighborhood development has emerged as a critical strategy to integrate ecological, social, and economic sustainability into built environments. However, green construction projects—particularly those incorporating unique cultural and landscape elements—carry inherently higher complexity and uncertainty compared to conventional projects, making accurate cost estimation particularly challenging [1]. Cost accuracy in the planning phase is a fundamental determinant of project success. Inaccurate estimates often lead to budget overruns,

project delays, and stakeholder disputes. The accuracy of a cost estimate is influenced by a multitude of factors, including the quality of scope documentation, the competency of estimators, the availability of reliable pricing data, and the effectiveness of risk management procedures [2]. In the context of green neighborhood projects, additional risks arise from the need to integrate environmental standards, sustainable materials, and specialized construction methods that may not be well-understood by estimators.

The Jogja Planning Gallery (JPG) project, located in Yogyakarta, Indonesia, serves as the case study for this research. JPG represents a contemporary green neighborhood development for cultural tourism, combining landscape design, architectural heritage, and sustainability principles.

The project's multidisciplinary nature and green performance requirements introduced significant estimation risks that warranted systematic investigation.

Previous studies have examined risk factors in construction cost estimation from various perspectives [3,4,5]. However, research specifically addressing the quantitative relationship between identified risk categories and cost accuracy indicators—particularly in the context of green neighborhood projects in developing countries—remains limited. This study seeks to address this gap by developing a statistically validated regression model linking risk variables to cost accuracy.

The specific objective addressed in this paper corresponds to: How can a relationship model between cost estimation process risks and cost accuracy be developed? The findings contribute to the body of knowledge on risk-informed cost estimation and offer practical guidance for project teams working on green neighborhood developments

II. LITERATURE REVIEW

2.1 Cost Estimation in Construction Project

Cost estimation is a systematic process of predicting the financial resources required to complete a construction project. It encompasses activities such as scope identification, quantity take-off, unit price determination, risk allowance incorporation, and document preparation [6]. The quality of cost estimates is directly related to the maturity of project information available at the time of estimation. During the planning phase, estimates are typically prepared with incomplete design information, making them susceptible to significant deviation from actual costs.

Several key dimensions of cost accuracy have been identified in the literature. Scope quality refers to the clarity and completeness of the project scope definition, as undefined or poorly described scope elements are a primary driver of cost overruns [7]. Information quality pertains to the accuracy and reliability of input data used in the estimation process. Uncertainty level captures the inherent unpredictability in project conditions, market prices, and design assumptions. Estimator performance reflects the competence, experience, and

professional judgment of the cost estimator. Finally, estimation procedure quality describes the rigor and standardization of the estimation methodology applied.

2.2 Risk in Cost Estimation Processes

Risk in project management is defined as an uncertain event or condition that, if it occurs, has a positive or negative effect on project objectives [8]. In the context of cost estimation, risks predominantly manifest as negative uncertainties that increase the probability of budget overruns. The Project Management Body of Knowledge (PMBOK) provides a structured framework for risk identification, qualitative analysis, quantitative analysis, and risk response planning.

Qualitative risk analysis involves assessing the probability and impact of identified risks to prioritize them for further attention. The risk score is calculated as the product of probability and impact values, and risks are classified using a probability-impact matrix into low (0.01–0.06), moderate (0.07–0.18), and high (0.19–0.72) categories [8]. High-risk events require immediate attention and targeted mitigation strategies.

Risk factors specific to the cost estimation process have been documented in various studies. Common risk categories include incomplete or unclear project scope, inadequate drawing and specification documents, poor work breakdown structure (WBS) implementation, inadequate resource planning, inaccurate unit price determination, errors in volume calculation, insufficient contingency planning, and deficiencies in tender document preparation [9, 10].

2.3 Green Neighborhood Projects

Green neighborhoods are planned communities designed to minimize environmental impact through sustainable site design, energy efficiency, water conservation, material selection, and indoor environmental quality [11]. In Indonesia, green building and neighborhood standards are regulated under the Green Building Council Indonesia (GBCI) GreenShip Rating Tools and the Minister of Public Works and Housing Regulation No. 21 of 2021. Compliance with these standards introduces additional complexity to the cost estimation process, as estimators must account for

green-specific materials, technologies, and certification requirements that may differ substantially from conventional construction practices.

Several studies have noted that the premium cost of green construction compared to conventional construction ranges from 5% to 20%, depending on the level of green certification pursued and the availability of local sustainable materials [12, 13]. This cost premium, combined with the limited experience of estimators in green construction, creates elevated risk exposure throughout the estimation process.

III. RESEARCH METHODOLOGY

3.1 Research Design and Data Collection

This study employs a quantitative research approach. Data were collected through a structured questionnaire administered to 40 respondents selected using purposive sampling based on their professional experience in construction cost estimation, project management, and green building. Respondents included practitioners from consulting firms, contractors, and government agencies directly involved in the JPG project or in comparable green neighborhood projects in Indonesia.

Respondent profiles were as follows: by education level, 7.5% held doctoral degrees (S3), 30% held master's degrees (S2), and 62.5% held bachelor's degrees (S1). By organizational position, 10% were at the Top Management Level (Director, Team Leader), 15% at the Middle Management Level (Manager, Chief Estimator, Department Head), and 75% at the Operational Level (Engineer, Staff, Practitioner). By work experience, 57.5% had 5–10 years of experience, 22.5% had 10–15 years, and 20% had more than 15 years.

3.2 Variables

The independent variables (X) consist of eight risk categories derived from 33 high-level risks identified from 45 potential risks in the cost estimation process. These categories, established through expert validation and literature review, are described in Table 1.

Table 1. Risk Category Variables (X) in Cost Estimation Process

Code	Risk Category	Description
X1	Project Scope Statement	Risks related to unclear or incomplete project scope definition
X2	Drawings/Design and Specifications	Risks related to inaccurate or incomplete design documents and technical specifications
X3	Work Breakdown Structure and Activities	Risks related to incorrect WBS coding and activity identification
X4	Resource Identification and Planning	Risks related to inadequate identification and scheduling of project resources
X5	Unit Price and Resource Determination	Risks related to errors in determining unit prices for labor, materials, and equipment
X6	Volume Calculation, Estimation and Cost Baseline	Risks related to inaccurate quantity take-off and baseline cost development
X7	Risk Allowance and Contingency	Risks related to insufficient contingency reserve and risk allowance planning
X8	Tender Document Preparation and Budget Approval	Risks related to errors in final document compilation, cost summary, and budget approval process

The dependent variable (Y) is cost accuracy, measured through five indicators: Y1 (Scope Quality), Y2 (Information Quality), Y3 (Uncertainty Level), Y4 (Estimator Performance),

and Y5 (Estimation Procedure Quality). These indicators were validated by experts prior to data collection.

3.3 Data Analysis Methods

Data analysis followed a sequential multi-stage process using SPSS version 27:

- (1) Homogeneity Test: Kruskal-Wallis H Test was used to verify that respondent groups (by education, position, and work experience) did not exhibit statistically significant differences in perception, confirming data homogeneity (Asymp. Sig. > 0.05 for all groups).
- (2) Data Sufficiency Test: Applied to verify that the collected sample size was statistically adequate for the subsequent analyses.
- (3) Validity Test: Item-total correlation was used; items with $r_{\text{calculated}} > r_{\text{table}}$ (at $\alpha = 0.05$, $df = 30$) were considered valid.
- (4) Reliability Test: Cronbach's Alpha was used; instruments with $\alpha > 0.60$ were considered reliable.
- (5) Correlation Analysis: Spearman's bivariate correlation was used to examine the direction and significance of the relationship between risk variables (X) and cost accuracy (Y).
- (6) Factor Analysis: Principal Component Analysis (PCA) was used to confirm the dimensionality of the risk variables, with KMO > 0.5 as the adequacy criterion.
- (7) Stepwise Multiple Linear Regression: Applied to develop predictive models linking risk categories to each cost accuracy indicator. The stepwise method was selected for its ability to automatically identify statistically significant predictors while eliminating non-significant variables.
- (8) Expert Validation (Delphi Method): Final model outputs were validated by three domain experts to confirm practical relevance and applicability.

IV. RESULT

4.1 Statistical Validity and Reliability

All items in the questionnaire passed the validity test with $r_{\text{calculated}} > r_{\text{table}}$ (0.349 at $\alpha = 0.05$, $df = 30$). Cronbach's Alpha values for all risk categories exceeded 0.60, confirming adequate reliability. Homogeneity tests using Kruskal-Wallis H Test returned Asymp. Sig. values well above 0.05 for all three grouping variables (education, position,

and work experience), indicating that respondent perceptions were homogeneous and the data could be analyzed as a unified pool.

4.2 Correlation Analysis

Spearman's correlation analysis revealed that all eight risk categories (X1–X8) exhibited statistically significant negative correlations with all five cost accuracy indicators (Y1–Y5), with Sig. (2-tailed) values below 0.05. The negative correlation direction confirms that as risk levels increase, cost accuracy decreases. This bidirectional inverse relationship underscores the systemic nature of risk in the estimation process—elevated risk in any category progressively erodes the reliability of the final cost estimate.

4.3 Factor Analysis

Factor analysis using PCA indicated that all eight risk variables load strongly onto a single component, with factor loadings ranging from 0.823 (X4) to 0.916 (X5). The KMO value was 0.847 (> 0.5) and Bartlett's Test of Sphericity was significant ($p < 0.001$), confirming the adequacy of data for factor analysis. The single component extracted explained 74.843% of the total variance, confirming that the risk categories collectively represent a unidimensional construct of Cost Estimation Process Risk that uniformly impacts cost accuracy.

4.4 Stepwise Multiple Linear Regression Results

Stepwise multiple linear regression was applied separately for each of the five cost accuracy indicators. The resulting regression equations, their explanatory power, and dominant risk variables are summarized in Table 2.

Table 2. Summary of Multiple Linear Regression Models

No	Y Indicator	Regression Equation	Adj. R ²	Dominant	Sig.
1	Y1 – Scope Quality	$Y' = 24.262 - 0.059X_2 - 0.095X_8$	48.2%	X8	0.000

No	Y Indicator	Regression Equation	Adj. R ²	Dominant	Sig.
2	Y2 – Information Quality	$Y' = 18.445 - 0.044X_2 - 0.078X_8$	53.0%	X8	0.000
3	Y3 – Uncertainty Level	$Y' = 24.435 - 0.063X_2 - 0.096X_8$	51.2%	X8	0.000
4	Y4 – Estimator Performance	$Y' = 24.783 - 0.126X_8 - 0.035X_1$	52.9%	X8	0.000
5	Y5 – Estimation Procedure Quality	$Y' = 18.615 - 0.042X_2 - 0.078X_8$	49.9%	X8	0.000

individual line-item errors into significant overall deviations.
 RISK 33: Insufficient estimator understanding of project execution methods — Inadequate knowledge of sustainable construction methods and sequencing can result in incorrect resource allocation and method-related cost assumptions. These risks are concentrated at the final stage of the cost estimation process—tender document preparation—which integrates all upstream estimation activities. Consequently, any errors introduced at this stage are carried directly into the approved budget, with no subsequent corrective mechanism before cost commitment.

All ANOVA F-tests were significant at $p < 0.001$, confirming that the regression models are statistically valid. The Adjusted R² values indicate that the identified risk factors explain between 48.2% and 53.0% of the variance in cost accuracy indicators, with the remaining variance attributable to factors beyond the scope of this study.

4.5 Dominant Risk Factor: X8 – Tender Document Preparation and Budget Approval

The most noteworthy finding is the consistent dominance of X8 (Tender Document Preparation and Budget Approval) across all five regression models. X8 appeared in every regression equation with the largest standardized beta coefficient, indicating it is the single most influential risk category affecting cost accuracy.

The specific high-level risks comprising X8 include:

RISK 30: Errors in determining unit prices for work items. This risk directly undermines the financial foundation of the estimate, as unit prices are the primary input to all cost calculations.

RISK 31: Insufficient estimator comprehension of green neighborhood project scope. Estimators unfamiliar with the ecological, landscape, and sustainability requirements of green neighborhoods are prone to omit or misclassify scope elements, leading to systematic underestimation.

RISK 32: Errors in cost summary calculations. Mathematical and aggregation errors in the final bill of quantities and cost sheets can compound

4.6 Secondary Influencing Factor: X2 – Drawings/Design and Specifications

X2 (Drawings/Design and Specifications) was identified as the second dominant risk factor, appearing in the regression equations for Y1, Y2, Y3, and Y5. Inaccurate or incomplete design documentation is a well-documented risk in construction cost estimation literature. In the context of green neighborhood projects, design specifications must align with green rating criteria, which adds complexity to the documentation requirements. Estimators relying on incomplete design information are forced to make assumptions that may deviate significantly from actual conditions, thereby reducing estimate accuracy.

X1 (Project Scope Statement) appeared as the secondary predictor for Y4 (Estimator Performance), suggesting that clarity of scope definition is particularly important for supporting estimator competence and judgment

4.7 Interpretation of Regression Models

Each unit increase in the X8 risk score is associated with a reduction in cost accuracy indicators ranging from 0.078 (Y2 and Y5) to 0.126 (Y4). Similarly, each unit increase in X2 risk score reduces cost accuracy indicators by 0.044 (Y2) to 0.063 (Y3). The negative coefficients across all models are consistent with the correlation analysis results, confirming the inverse relationship between risk exposure and cost accuracy.

The regression constants (ranging from 18.445 to 24.783) represent the theoretical cost accuracy levels when all risk variables are at zero, a

baseline that corresponds to an idealized condition with no estimation risks. These constants serve as benchmarks against which the deteriorating effect of risk exposure can be measured and communicated to project stakeholders.

4.8 Expert Validation

The regression model results were subjected to expert validation using the Delphi method with three senior practitioners: a Director from a design consulting firm (23 years experience, Master's degree), the Head of Cipta Karya Division from the Yogyakarta Province Public Works Agency (18 years experience, Master's degree), and a Chief Estimator from a project management consultant firm (8 years experience, Bachelor's degree). All three experts confirmed the dominance of X8 and agreed that tender document preparation represents the highest-stakes phase of the cost estimation process in green neighborhood projects. The experts further noted that the combined influence of X8 and X2 is particularly pronounced in green projects due to the relatively limited availability of standardized green-specification cost databases in Indonesia.

V. DISCUSSION

The findings of this study align with and extend existing literature on risk-driven cost overruns in construction projects. The identification of tender document preparation as the dominant risk category is consistent with previous research emphasizing the critical role of the final estimation stage in determining project cost accuracy [2, 3]. What this study adds, however, is a quantitatively validated, context-specific regression model applicable to green neighborhood projects—a relatively underexplored typology in cost risk research.

The unidimensionality of the risk construct identified through factor analysis has an important practical implication: while the eight risk categories differ in their specific manifestations, they collectively represent a unified risk dimension. This means that risk management efforts that improve any one category will likely produce positive spillover effects on overall estimation quality, as the underlying risk exposure is structurally interconnected.

The Adjusted R^2 values (48.2%–53.0%) indicate that the model captures roughly half of the variance in cost accuracy. The remaining unexplained variance likely reflects external factors not covered in this study, such as macroeconomic conditions, supply chain volatility, inflation, government policy changes, and force majeure events. Incorporating these variables in future models would improve predictive power and practical applicability.

From a theoretical perspective, this study demonstrates the utility of regression-based risk-accuracy models as a bridge between qualitative risk assessment and quantitative decision support in construction project planning. The model provides project owners and estimators with a systematic basis for understanding how specific risk behaviors translate into measurable losses in cost accuracy, thereby enabling more informed risk prioritization and mitigation resource allocation.

VI. CONCLUSION

This study developed a quantitative relationship model between cost estimation process risks and cost accuracy in green neighborhood projects, using the Jogja Planning Gallery project as a case study. The following conclusions are drawn:

1. From 45 identified risks, 33 were classified as high-level risks. These were grouped into 8 risk categories (X1–X8) through qualitative risk analysis using the PMBOK probability-impact matrix.
2. All eight risk categories exhibited statistically significant negative correlations with all five cost accuracy indicators, confirming that risk increase systematically reduces cost accuracy.
3. Factor analysis confirmed that the risk variables form a unidimensional construct, collectively representing Cost Estimation Process Risk as a single latent factor (74.843% of explained variance; KMO = 0.847).
4. Stepwise multiple linear regression produced five validated models with Adjusted R^2 values ranging from 48.2% to 53.0%. The variable X8 (Tender Document Preparation and Budget Approval) consistently emerged as the most dominant risk factor across all

models, followed by X2 (Drawings/Design and Specifications) in four of the five models.

5. The dominant risks within X8 include errors in unit price determination, insufficient estimator understanding of green project scope and execution methods, and calculation inaccuracies in cost summaries.

These findings have important practical implications. Project teams should prioritize risk mitigation efforts at the tender document preparation stage through document standardization, multi-level verification procedures, and targeted capacity building for estimators in green construction methods and sustainability specifications. Furthermore, improved completeness of design documentation (X2) should be pursued as a complementary measure to reduce second-order risk exposure.

Future research should investigate the incorporation of external economic variables, expand the respondent pool to include a broader geographic and project-type range, and explore the application of advanced machine learning methods for cost accuracy prediction in green construction contexts.

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