



# Project Cost Estimation Using a Stepwise Approach: a Case Study of an Infrastructure Project in Gresik Regency, East Java

Siswoyo<sup>1,a)</sup>, H. Soepriyono<sup>2</sup>, Akbar Bayu Kresna S<sup>3</sup>. Nia Saurina<sup>4</sup>, Lestari Retnawati<sup>5</sup>

<sup>1,2,3</sup>Department of Civil Engineering, Faculty of Engineering, Universitas Wijaya Kusuma Surabaya

<sup>4,5</sup>Department of Informatics, Faculty of Engineering, Universitas Wijaya Kusuma Surabaya

<sup>a)</sup>Corresponding author: [siswoyo60@uwks.ac.id](mailto:siswoyo60@uwks.ac.id)

**Abstract.** There are many studies related to cost estimation applied in a project, but only a few employ using “stepwise” method. This approach is expected to assist in solving complex problems by establishing a criteria hierarchy, subjectively assessed by interested parties, and incorporating various considerations to develop weights or priorities. The foundation of the stepwise approach relies on well-documented findings, which assert that 80% of the total project cost corresponds to the 20% most expensive components of the work. The research systematically collected data for project development estimates based on the bill of quantities from each year, as well as the HSPK (activity main unit price) in Gresik Regency from 2016 to 2018. This research aims to develop a conceptualized estimation model that provides clear, rapid, and relatively accurate initial project cost information. The results of this research include analysis of stepwise approach on cost realization, analysis of accuracy of the cost estimation model for buildings using the stepwise method, and an analysis of the cost of road and bridge infrastructure projects to facilitate completion in Gresik Regency. The research concludes that the analysis of the Cost Significant Model's impact on cost realization in the Public Works and Spatial Office's Highways Division in Gresik Regency has resulted in a cost estimation model for road development with an accuracy range from -12.7% to 16.0%, with an average accuracy rate of 0.59%. Additionally, there is a very strong correlation (R) of the independent variable (work in Division 2) and the total development cost, indicating that fluctuations in the cost of significant components are closely linked to changes in the overall development cost. The analysis of infrastructure project costs related to roads and bridges for project completion revealed that the highest value among independent variables is associated with Division 7, at Rp. 4,403,054 per m<sup>2</sup>. This suggests that the cost of Division 7 work is the most influential, while Division 1 (X1) has the lowest cost, at Rp. 35,589 per m<sup>2</sup>. Furthermore, there is a work component with zero cost, namely, Division 4 works.

**Keywords:** Cost Estimate, stepwise, HPS, Gresik Regency

## INTRODUCTION

Related to cost estimate, there are already many studies applied in a project, but there is a few applying using “stepwise” method. By applying the method, it is expected to assist for solving complex problems by composing a criteria hierarchy, it is assessed subjectively by interested parties then drawing various considerations to develop weights or priority [1] The foundation of stepwise approach is relying on the well - documented findings which assert that 80% of the total project cost is attributed to the 20% the most expensive work items. The research data were systematically collected for project development estimates, based on the bill of quantities for each year, as well as the HSPK (activity main unit price) in Gresik Regency from 2016 to 2018 [2].

Gresik Regency is a regency located on the north coast of East Java and is characterized by mostly low-lying coastal areas. This landscape is an extension of the North Kapur Mountains. In the central region, there are lowlands

and undulating areas, with some areas being marshy. The eastern edge of the Kendeng Mountains also extends into this central area.

Selection of the foundation type for retaining walls is a crucial step in building planning. The stability of slopes can be compromised by various human activities and natural conditions. Unstable slopes pose significant risks to their surrounding environments, highlighting the need for slope stability analysis [3].

Department of Public Works and Spatial Gresik Regency, particularly Division of Highways, employs several methods for cost estimation based on project planning stages, such as Engineering Estimate (EE) and Owner Estimate (OE). During the initial project planning phase, owners or principals must perform cost estimation to prepare the project budget. Therefore, there is a need for an easily applicable, accurate, and instantly accessible cost estimation model [4]. Cost planning plays a critical role in the construction planning process, and the implementation of construction requires detailed analysis and documentation since cost estimation significantly impacts project success. The cost development model used is based on the principles of the Cost Significant Model Concept [5].

From a contractor's perspective, an ideal conceptual estimation model should exhibit certain characteristics. It should be simple, reasonably accurate, capable of providing instant feedback, consist of easily measurable elements, and effectively describe fieldwork operations. Such a model can serve as a reference for work monitoring and implementation [6].

Cost estimating serves as an important factor in the construction plan process in the context of Division of Highways, Department of Public Works, and Spatial Gresik Regency [7]. It requires a comprehensive review during the development phase before the physical implementation of construction. Cost estimation significantly impacts the success of both the project and the company [8].

Stepwise is one of the construction total cost estimation models based on past bidding data. It places significant reliance on the prices that have the most influence on the total project cost. This reliance forms the foundation for estimation, which is translated into a multiple regression formulation [9]. Stepwise Conceptual is a method for comparing cost estimations obtained from previous data. It involves determining the volume unit, such as area in square meters (m<sup>2</sup>) or per cubic meter (per-m<sup>3</sup>) for the building. Subsequently, the overall estimated cost is adjusted for inflation in the current year of the project's implementation. The unit price of work in each construction year is then calculated and serves as the price reference for subsequent pricing considerations [10].

This study aims to develop a conceptual estimation model that can provide clear, immediate, and easily accessible initial project cost information with reasonably accurate results. This study includes an analysis of the factors involved in the application of the stepwise method to cost realization, an assessment of the model's accuracy in estimating the cost of building projects using the stepwise approach, and an analysis of the costs associated with road and bridge infrastructure projects for project completion in Gresik Regency.

## **MATERIAL AND METHODS**

Principally, the Cost Significant Model (CSM) is one of the total cost estimation models for a project based on historical cost data, and it relies on the most significant prices to influence the total project costs as a foundation for predicting estimates [11]. It is essential for identifying project costs across different stages: (1) Conceptual development stage, where project costs are calculated globally based on a specific per-capacity price, (2) Construction design stage, where project costs are detailed based on work volume and unit price information, (3) Tender stage, where project costs are calculated by multiple contractors to secure the best offer, relying on comprehensive technical specifications and work drawings to establish a work contract, and (4) Implementation stages, where project costs are calculated with higher precision, taking into account the quantity of work, shop drawings, and implementation methods [12].

The definition of cost estimation, according to the National Estimating Society USA, is as follows: 'Cost estimation is the art of approximating the potential total cost of an activity based on available information at the current time [13]. Cost estimation is closely related to cost analysis, which involves studying the costs of previous activities to serve as a reference for preparing cost estimates. In other words, preparing cost estimates is about anticipating, calculating, and making predictions about potential issues that may arise [14]. Meanwhile, cost analysis focuses on the study and discussion of past activity costs to provide recommendations [15].

The 'conceptual Cost Significant Model' method involves several steps based on the analysis of previous project data. This includes excluding work items that, while sometimes numerous, do not have distinct work item classifications. Work item integration can be applied when the work items have similar unit sizes [16].

The primary requirement is for the estimator to identify any essential considerations in a bid or the engineering approach needed to meet the project requirements. Developing a cost model is necessary to facilitate quick calculations, enhance project comprehension, and effectively communicate complex concepts [17].

Cost estimates are contingent on the progress of the project implementation timeline. Consequently, stages are established based on the detailed project development phases. [18]:

- 1) Preliminary estimation: it is made at the initial stage of the project to approach the economic feasibility of the project. It is also used for controlling financing and in price competition.
- 2) Detailed estimation: it is made based on calculating work volume, costs, and detailed work unit prices.
- 3) Definitive estimation: it is a description of the financing and complete accountability for a project with only a small possibility of error.

In a construction project, the total cost of the project is the sum of the cost components which include labor costs, material costs, equipment costs, indirect costs, and profits which the percentage can be seen in Figure 1.

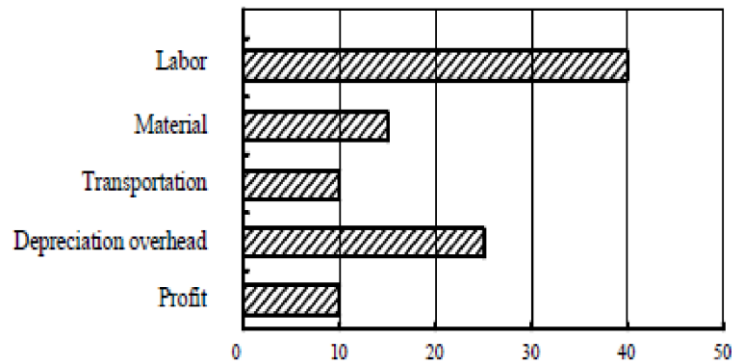


FIGURE 1. Sum of The Cost Components

Source : [19]

### Cost Significant Model

The tender process in Indonesia is sometimes influenced by local culture. Contractors often provide only a brief identification and description of project requirements and engage in price negotiations. The Cost Significant Model is based on findings that are adequately documented, showing that 80% of the total project cost is associated with 20% of the most expensive work items [20].

The total value of a project is typically calculated by multiplying the total price of cost significant packages by appropriate factors, usually around 1.25. This gross value varies depending on the category and analysis of historical data. The planned work package reflects the field implementation [21], allowing for effective feedback and control. This method typically involves only 10% of the number of conventional budget items [22].

Simplifying this model reduces the time required for cost estimation compared to traditional cost budgets, which often consist of thousands of items. Cost Significant Models can achieve cost estimations within a 5% margin of accuracy, with the final calculation being even more precise, typically within a 1% margin. The accuracy can be improved or reduced by enhancing the model and relying on available data [23]."

### Project Cost Estimation

The use of project cost estimation by various professionals is outlined in Table 1. Estimation serves different purposes for different stakeholders [24]:

- 1) For owners, it is essential to evaluate project feasibility, assess the continuation of investments, determine the economic value of the project, and establish cash inflow and outflow requirements.

- 2) Planners rely on estimation to guide the design's implementation and ensure it aligns with project investment goals. It is crucial for planners to make informed choices about materials and project size that fit within the developer's budget constraints and meet the owner's satisfaction.
- 3) Contractors use cost estimates to determine tender values and identify potential benefits, enabling them to execute the project as planned.
- 4) Project managers rely on estimates to facilitate successful project completion by aligning with the budget set by the project planner.

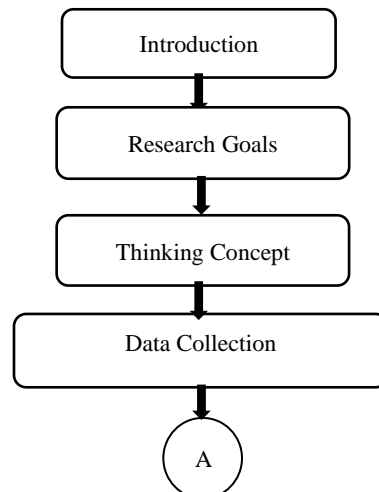
### Based on AACE International

**TABLE 1.** Cost Estimate Classification Matrix for Process Industry  
Source [25]

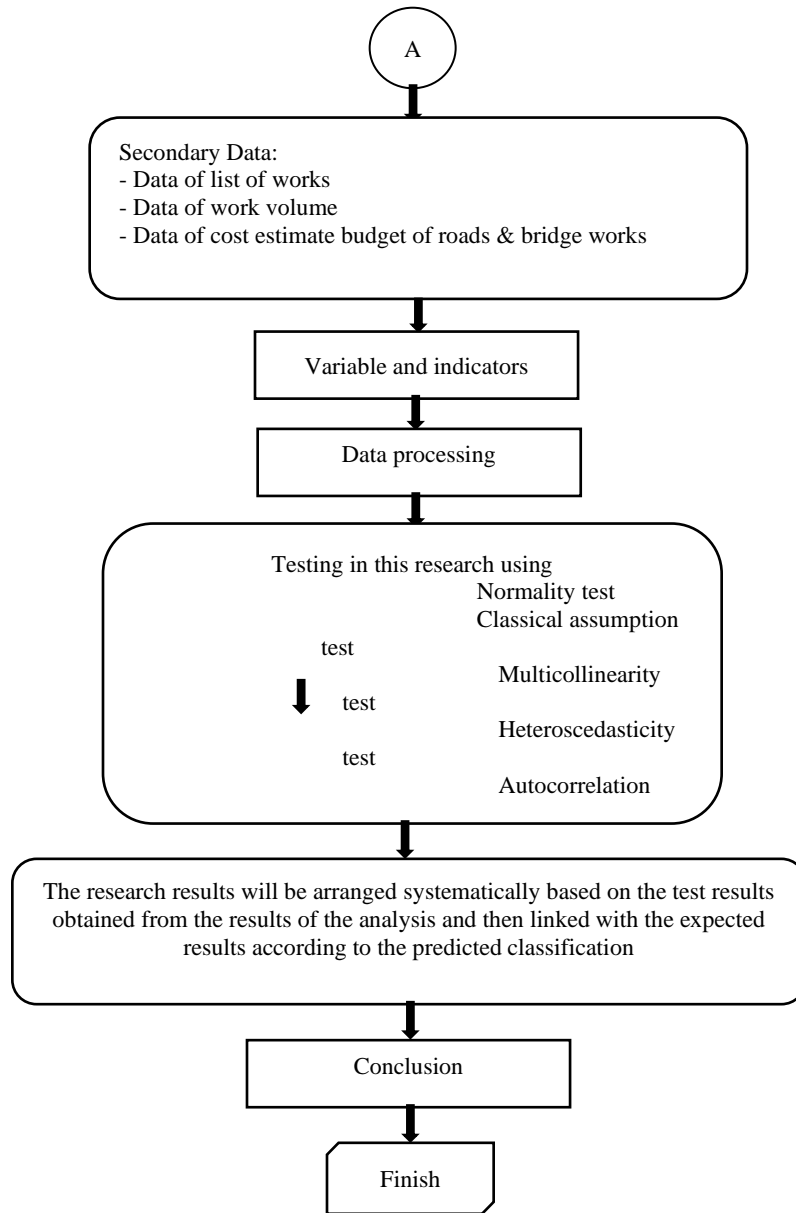
ESTIMATE CLASS	Primary Characteristic	Secondary Characteristic		
	MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES Expressed as % of complete definition	END USAGE Typical purpose of estimate	METHODOLOGY Typical estimating method	EXPECTED ACCURACY RANGE Typical variation in low and high ranges <sup>[a]</sup>
Class 5	0% to 2%	Concept screening	Capacity factored, parametric models, judgment, or analogy	L: -20% to -50% H: +30% to +100%
Class 4	1% to 15%	Study or feasibility	Equipment factored or parametric models	L: -15% to -30% H: +20% to +50%
Class 3	10% to 40%	Budget authorization or control	Semi-detailed unit costs with assembly level line items	L: -10% to -20% H: +10% to +30%
Class 2	30% to 75%	Control or bid/tender	Detailed unit cost with forced detailed take-off	L: -5% to -15% H: +5% to +20%
Class 1	65% to 100%	Check estimate or bid/tender	Detailed unit cost with detailed take-off	L: -3% to -10% H: +3% to +15%

Notes: [a] The state of process technology, availability of applicable reference cost data, and many other risks affect the range markedly. The +/- value represents typical percentage variation of actual costs from the cost estimate after application of contingency (typically at a 50% level of confidence) for given scope.

### Research Flow Chart



**FIGURE 2.** Research Flow Chart (1)



**FIGURE 3.** Research Flow Chart (2)

## **RESULTS AND DISCUSSION**

The data used as a research tool is the total cost budget, excluding Value Added Tax (VAT). The data can be seen in table 2 and Table 3.

**TABLE 2.** Project Budget of 2016-2019 Division of Highways, Gresik Regency

Division Of Highways
Road Construction
Bridge Construction
Rehabilitation / Maintenance Of Highways Laboratory
Procurement Of Public Road Lightning
Construction Of Village Road And Brige
Management Of Special Allocation Funds For Assignment Of Road Division, Connectivity Supporting Sub-Division
Road Rehabilitation / Maintenance

**TABLE 3.** Project Budget of 2016–2019 Division of Highways, Gresik Regency (Continued)  
*Source:* Researcher's Personal Documents

The field of civil development		2016	2017	2018	2019
		162,006,456,385,00	135,156,344,262,00	186,361,080,500,00	202,250,215,571,93
X1	Road construction	94,806,456,385,00	56,742,199,552,00	96,647,712,400,00	142,019,963,600,00
X2	Bridge construction	21,000,000,000,00	17,087,678,240,00	18,277,845,000,00	41,175,148,944,93
X3	Rehabilitation/maintenance of the animal husbandry laboratory	100,000,000,00	93,400,000,00	458,633,000,00	919,164,800,00
X4	Provision of public street lighting	10,000,000,000,00	12,001,960,385,00	12,101,459,300,00	22,505,417,596,00
X5	Development and rural roads	12,100,000,000,00	7,465,708,085,00	20,246,848,300,00	13,922,593,760,00
X6	Management of special allocation funds for assignments in the road sector, connectivity support sub-sector	24,000,000,000,00	21,328,965,000,00	23,677,280,500,00	43,016,617,871,00
X7	Road rehabilitation / maintenance		20,436,432,000,00	17,042,302,000,00	28,690,309,000,00

To create comparable project budgets, the researchers needed to standardize the project budget to a single fiscal year. In this context, the total project budget (Y) and its individual components (X1 to X8) were adjusted for the Division of Highways. Additionally, all data was further adjusted to account for the time value effect, which involved projecting the data to the year 2020.

The dataset includes detailed information for each work package, comprising total costs (Y) and associated work items, which are utilized as independent variables (X). The independent variable data are as follows:

1. General
2. Drainage Work
3. Earthworks
4. -
5. Grained Pavement and Cement Concrete
6. Asphalt Pavement
7. Structure
8. Condition Returns

### Data Description

Data description is employed to present data in a quantitative form without involving decision-making processes. The data is presented descriptively, without undergoing further analytical techniques. Additionally, cost-significant items are identified as those comprising the largest portion, accounting for 80% or more of the total cost. These identified independent variables, representing the cost-significant items, are subsequently utilized in the analysis. The following table illustrates the percentage for each work component:

**TABLE 4.** Percentage of Each Work Component  
*Source: Processed Data*

Variable	Works	Cost Total (Rp./m <sup>2</sup> )	Percentage	Rank
X1	Division 1	35.589	0,44%	7
X2	Division 2	1.770.790	21,99%	2
X3	Division 3	373.523	4,64%	5
X4	Division 4	-	0,00%	8
X5	Division 5	1.037.467	12,88%	3
X6	Division 6	378.499	4,70%	4
X7	Division 7	4.403.054	54,67%	1
X8	Division 8	55.163	0,68%	6
<b>Cost Total</b>		<b>8.054.085</b>	<b>100,00%</b>	

Table 4 shows the percentage of each division of work as well as ranks starting from the division of work that has the largest cost to the cost with the smallest percentage of costs. It is known that there are three cost divisions with a cost percentage of more than 80%, as presented in Table 5 below:

**TABLE 5.** Cost Significant Item  
*Source: Processed Data*

Variables	Works	Cost Total	Percentage
X7	Divisi 7	4.403.054	54,67%
X2	Divisi 2	1.770.790	21,99%
X5	Divisi 5	1.037.467	12,88%
<b>Cost Total</b>		<b>7.211.311</b>	<b>89,54%</b>

### **Determining Cost Significant Item**

The three divisions of work in the previous sub-chapter, known as the cost significant items are then calculated as future values used as projections for 2020 costs (see Appendix 3). After that, the determination of cost-significant items will be analyzed using the SPSS program using a stepwise regression analysis technique, namely a method for determining the dominant independent variable. SPSS input data is as follows:

**TABLE 6.** SPSS input data  
*Source: Appendix 3*

No	X2	X5	X7	Y
1	123.852,50	134.219,78	781.660,81	1.113.722,81
2	449.245,49	119.495,45	831.722,63	1.452.348,85
3	0,00	254.222,86	205.579,08	867.450,21
4	432.813,13	58.901,45	821.208,82	1.380.863,67
5	353.127,94	46.099,63	863.556,41	1.354.968,81
6	0,00	434.136,53	615.254,70	1.152.436,85
7	591.499,72	93.091,19	747.962,40	1.573.900,06

Furthermore, it is created a statistical test based on SPSS as the following equation:

$$Y = 609.059,75 + 1,034 X_2 + 0,719 X_5 + 0,369 X_7$$

Subsequently, the study conducted the F-test, t-test, and model test, yielding the following results:

The results of the estimated cost-significant model presented above were obtained through comparisons with the implementation costs (actual costs) of the reviewed projects. Notably, the average value of CMF is 1.00000, indicating highly accurate predictions of the total cost of road construction using the cost-significant model, aligning closely with the actual cost of road construction according to the HPS.

The accuracy rate is determined by calculating the difference between the estimated cost-significant model and the cost of implementation, which is then divided by the cost of implementation and multiplied by 100%. For comparison, the accuracy of the method previously utilized, known as the road volume parameter method for implementation costs, is also calculated. The results of the road construction estimation model are presented in Table 7..

**TABLE 7.** Accuracy of Cost Estimation Model of Road Construction  
*Source:* Researcher's Personal Documents

No	Actual cost total (Rp./m)	Prediction of cost total (Rp./m)	Model accuracy
1	1.113.722,81	1.121.987,49	0.7%
2	1.452.348,85	1.466.332,51	1.0%
3	867.450,21	867.772,41	0.0%
4	1.380.863,67	1.401.871,19	1.5%
5	1.354.968,81	1.325.881,85	-2.1%
6	1.152.436,85	1.148.303,50	-0.4%
7	1.573.900,06	1.563.542,30	-0.7%
Average	1.270.813,04	1.270.813,03	0.00%

Table 7 presents the model accuracy rates. A positive rate indicates that the cost estimation exceeds the implementation cost (actual cost). Conversely, a negative model accuracy rate indicates that the cost estimation is less than the implementation cost (actual cost). The accuracy of the "Cost Significant Model" falls within the range of -2.1% to +1.5%, with an average of +0.0%. Therefore, the cost estimation using the developed "Cost Significant Model" is highly accurate.

## CONCLUSION

Based on the results of the taken research, the following conclusions can be obtained:

1. The analysis results of the influence of the Cost Significant Model factor in its application to the realization of costs within the Department of Public Works and Spatial Planning in the Division of Highways, Gresik Regency conclude that:
  - a. The cost estimation model of the road construction is:  
 $Y = 609,059.75 + 1.034 X_2 + 0,719 X_5 + 0,369 X_7$   
 The cost estimation accuracy rate for the cost significant model ranges from -2.1% to 1.5%, with an average accuracy rate of 0.0%.
  - b. The correlation (R) between the independent variables (Division 2, Division 5, and Division 7) and the total construction cost is 0.998, indicating a very strong correlation. This means that any increase or decrease in the cost of a cost significant item will result in a corresponding increase or decrease in the total development costs.
  - c. Among the work divisions, Division 2 has the most significant influence on the budget planning for road construction per square meter volume, followed by Division 5 and Division 7, respectively.
2. The accuracy of the cost estimation model for buildings using the Cost Significant Model method indicates that the average cost per square meter of the estimated cost significant model is Rp. 1,270,813.03, while the actual HPS



cost is Rp. 1,270,813.04. The difference between CSM and the actual HPS cost is nearly zero, with a CMF (Cost Model Factor) of 1.00000%. The average accuracy rate is very small, at 0.00%.

3. The results of the cost analysis of road and bridge infrastructure projects to complete the project conclude that:
  - a. The highest independent variable value is in the work of Division 7 (X7), which is Rp. 4,403,054 per square meter. This illustrates that the work costs of Division 7 are the most dominant, while the work of Division 1 (X1) has the lowest cost, at Rp. 35,589 per square meter. Additionally, there is one work component, Division 4, that has zero costs..
  - b. A Cost Significant Item is a summary of work costs that make up  $\geq 80\%$  of the total, including the works in Division 2, Division 5, and Division 7.
  - c. Analysis using SPSS confirms that works in Division 2 (X2), Division 5 (X5), and Division 7 (X7) significantly affect the total construction cost.

## REFERENCES

- [1] ANSI/PMI 99-001-2008, "A Guide to The Project Management Body of Knowledge ( PMBOK Guide )", Fourth Edition. *Project Management Institute, Inc.* Pennsylvania, 2008.
- [2] Arikunto, Suharsimi, "Research Procedure: A Practical Approach". *Publisher, PT. Rineka Cipta*, Jakarta, 2002.
- [3] Gaspersz, Vincent, "Integrated Total Quality Talent Management: 50 Concepts, Models and Key Analyses in Total Quality, Practical Human Capital, and Talent Management System". *Publisher, PT. Gramedia Pustaka Utama*, Jakarta, 2013.
- [4] Gaspersz, Vincent, "Total Quality Management for Business and Industrial Practitioners". *Publisher, PT. Niaga Swadaya*, Jakarta, 2011.
- [5] Harialdi, "Statistics, Statistical Principles for Engineering and Science", *Publisher, Erlangga*, 2005.
- [6] Kerzner, Harold, "Project Management: A System Approach to Planning, Scheduling, and Controlling". Eleventh Edition. *John Wiley & Sons, Inc.* New York, 2013.
- [7] Kuehn, Ursula. "Project Management : Integrated Cost and Schedule Control". Second Edition, *Management Concepts, Inc.* VA, 2011.
- [8] Mohsenijam A., Siu M.F., and Lu M., "Modified stepwise regression approach to streamlining predictive analytics for construction engineering applications", *Journal of Computing in Civil Engineering, ASCE. Volume 31, Issue 3*, 2017.
- [9] Larson & Gray, "Project Management, Managerial Process", 3<sup>rd</sup> Edition, *Publisher Andi, Yogyakarta*, 2006.
- [10] Muslich, Muhammad., "Quantitative Decision Making Method, Second Edition". *Publisher, PT. Bumi Akasara*, Jakarta. 2010.
- [11] Moetrisono, Harry., "Teaching Module of Master of Civil Engineering". *Applied Statistics Journal Volume 1, Issue 2*. 2012
- [12] Oetomo, Wateno., "Teaching Module of Master of Civil Engineering", Project Management: Diktat, *University of 17 Agustus 1945 Surabaya*, 2012.
- [13] Putra, Nusa., "Qualitative Research Method of Management", 1<sup>st</sup> Edition, *Publisher, PT. Rajagrafindo Persada*, Jakarta, 2013.
- [14] Soeharto, Imam, "Project Management: From Conceptual to Operational", *Publisher, Erlangga*, Jakarta, 1998.
- [15] Schmidt, Terry, "Strategic Project Management Made Simple: Practical Tools for Leaders and Teams", *John Wiley & Sons, Inc.* New Jersey, 2009.
- [16] Sinambela, Lijan Poltak, "Employee Performance: Theory, Measurement and Implementation". First Edition, *Publisher, Graha Ilmu*, Yogyakarta, 2012.
- [17] Sugiyono, "Administrative Research Methods: Complemented with R&D Methods", 18<sup>th</sup> Edition, *Publisher, CV. Alfabeta*, Bandung, 2010.
- [18] Leanne Riley, Regina Guthold, Melanie Cowan, Stefan Savin, et.al., "The World Health Organization STEPwise Approach to Noncommunicable Disease Risk-Factor Surveillance: Methods, Challenges, and Opportunities". *American Journal Public Health. Volume 106, Issue 1*, 2022.
- [19] Tunggal, Amin Widjaja. "Introduction to Quality Management". *Publisher, Harvarindo*, 2013.
- [20] Widianantri & Lenggogeni, "Construction Management", First Edition, *Publisher, PT Remaja Rosdakarya*. Bandung, 2013.

- [21] Ali Najah Abdulkadhim Alkhuadhan, "A new model for cost estimation construction project using Hybrid importance regression ensemble method". *International Scientific Journal about Logistics*. Volume 2, Issue 2, 2023.
- [22] Arash Mohsenijam, Ming Lu, Serhii Naumets, "Integrating model tree and modified stepwise regression in concrete slump prediction and steel fabrication estimating". *Canadian Journal of Civil Engineering*, 2020.
- [23] Trijeti, Sinung Tri Wibowo, "Comparison Of Estimated Cost Of Estimation With Detailed Cost Estimation In Building Projects", *International Journal Of Scientific & Technology Research Volume 9, Issue 02*, 2020.
- [24] Mohamed Ali Awwad; Ahmed Marei Al Radhi; Manoj Kumar Panigrahy; Suraj Kumar Gopal., "Cost Optimization in Mega Oil & Gas Projects". *International Petroleum Exhibition & Conference*, Abu Dhabi, UAE, 2021.
- [25] Gardner B.J., Gransberg D.D., and David J.H., "Reducing data-collection efforts for conceptual cost estimating at a highway agency". *Journal of Construction Engineering and Managemen*, Volume 142 Issue 11, 2016.