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Implementation of Regression Linear Method to predict WWTP cost for EIA: case study of ten malls in Surabaya City

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Abstract

This study aims to implement the linear regression method to generate a linear regression equation that can be used in the study of EIA (Environmental Impact Assessment) to predict the cost of WWTP (Wastewater Treatment Plant) of the data wastewater flow rate with case study of ten malls in Surabaya city.Some previous researchers have produced data on a linear regression WWTP construction costs and wastewater flow rate. In the EIA study in Indonesia, management and monitoring costs include costs of construction, operation and maintenance costs, and monitoring costs. Therefore, these costs will be calculated for WWTP of malls with unit prices prevailing in Surabaya city. The methodology of the study consists of the calculation of the construction cost, the calculation of operation and maintenance cost, the calculation of monitoring cost, and the process of making a linear regression curve. The result showed that from the ten malls, the smallest flow rate was 0.88 l/sec and 6.72 l/sec the largest, while the calculation of the cost was gained at the least as 577×10^6IDR and the biggest cost was 2163×10^6 IDR. The linear regression curve between the flow rate WWTP (as independent variables in the X axis) and the total cost WWTP (as dependent variables in the Y-axis) has produced a regression equation of Y = 358 + 271X. The result of the linear regression equation can be used directly by the EIA committee in Surabaya city and activityinitiator of mall to predict the cost of WWTP quickly and to decide the environmental feasibility of the mall.

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1. Introduction

The business plan includes mall activities that requires to formulate EIA studies in Indonesia because the total area of the mall building is generally more than 10,000 m^2 in accordance with the provisions of the constitution of the Republic of Indonesia No. 32/2009 [1] and the Regulation of the Minister of the Environment No. 5/2012 [2]. The environmental feasibility study of EIA is generally given when the techonology to manage the environmental impact is available and the cost to manage environmental impacts is not greater than the benefit. Malls in Surabaya citygenerally takeinto account the environmental impact on wastewater discharge from the mall activities that can potentially cause pollution to recipient river.

The initiator of each mall has calculated the benefits of mall activities through economic feasibility study.WWTP technology of a mall has already been widely available in the community and can be accessed easily in the internet. The problems that we are facing today is how to predict the cost of WWTP mall quickly compared with the benefits of mall activities.In the EIA study of malls, management and monitoring costs include the construction cost, the operation and maintenance cost, and the monitoring cost of WWTP mall.

Regression method is a method that has been applied to produce a linear regression equation of the WWTP construction cost data from the data flowrate [3, 4]. The method is appropriate to be implemented for EIA of malls in Surabaya city to predict the cost of WWTP mall quickly by using the linear regression equation and the data from the calculation of cost variations of ten malls in Surabaya and data of flowrate variation.

The purpose of this study is to implement the linear regression method to generate a linear regression equation that can be used in EIA studies to predict the WWTP cost of wastewater flowrate with ten malls in Surabaya as case study.

2. Literature Review

2.1. EIA study

Malls activities in Surabaya citywhich mainly generate environmental impact have conducted environmental impact assessment (EIA)generally. However, the environmental impact as in river pollution still occurs in Surabaya River. Republic of Indonesia Act No.32/2009 [1] states that every business and/or activity which generates significant impact towards environment is obligated to have an EIA study [2]. EIA initiator is obligated to involve public in the process [5] in activities such as socialization and public consultation [6, 7, 8]. The EIA documents authors are required to have certificate of competence. In making of the EIA documents, it is required to obey the rule [9]. The decision of environmental feasibility from the EIA study of malls in Surabaya City mainly is not based on the WWTP consideration cost because it is difficult to predict the magnitude of the cost. This regression equation is intended to help the EIA committee in Surabaya city to give a decision regarding the environmental feasibility after they know how much the cost of the WWTP is. The environmental impact during the activity process could also be prevented and resolved [10, 11].

2.2. Regression Equation

Huang [3] in his research has generated some linear regression equations as between the total construction cost of WWTP and a flow rate design for secondary treatment. In addition, the linear regression equation also generates secondary treatment with phosphorus removal and linear regression equation between the total cost of OM and the size of WWTP. Friedler & Pisanty [4] has also brought out linear regression equation between the design flow of WWTP and the construction costs of WWTP. There have been two research studies on linear regression equation between the construction costs of WWTP and the flow rate of WWTP wastewater with the applicable unit price costs in the USA before 1980[3] and 2006 [4].In this case study, it has also been added with the operation and maintenance costs and the monitoring costs for WWTP malls with a unit price of Surabaya city in 2013.Several studies on the regression analysis method has also been done by several researchers [12,13,14].

2.3. Wastewater Plants Cost

The WWTP cost includesthe construction costs, the operation and maintenance costs, and the monitoringcost.Construction costs are generally the sum of the cost of preparatory work, soil work, concrete and foundation work, and finishing work.Friedler & Pisanty [4] stated that the operation cost of WWTP for the city could reach 20-70% of the WWTPconstruction costs.While based on the Regulation of the Minister of Public Works [15], component of maintenance costs can include the costof the building age and depreciation, the cost of thebuilding damage, andthe cost of the building maintenance in which it can be set the total of 2% of construction costs per year.By mergingthe idea of Friedler & Pisanty [4] and the Regulation of the Minister of Public Works [15], it will be obtained the length of the WWTP operation ranging between 10 to 35 years (the cost is 20-70%). The components of the monitoring costs in Indonesia are generally made up of the cost of sampling and the cost of samples analysis in the laboratory.

3. Methodology

3.1. Calculation of construction cost

The calculation of WWTP construction cost refers to the image of DED WWTP for ten malls in Surabaya city. It has obtained drawings and pieces for each WWTP to calculate the volume of construction work activities for each WWTP. By using the unit price for the construction of Surabaya city in 2013, the WWTP construction cost is calculated by multiplying the volume of construction work activities for each WWTP and the unit price for each WWTP construction work.

3.2. Calculation of operation & maintenance cost

The calculation of WWTP operation and maintenance cost refers to the Regulation of the Minister of Public Works [12]. According to the rule, the cost of WWTP operation and maintenance can be calculated at 2% of the construction cost per year. Due to the long duration of WWTP operation, for 5 years, the operation and maintenance costs will be 10% of the construction costs. 5 years of operation corresponds to the monitoring time set for 5 years which is generally applied in the EIA study in Indonesia. Taking the operation and maintenance, monitoring time which is more than 5 years is estimated to significantly change the unit price of the construction work from the current price. In the Indonesian EIA study, it is difficult to predictmore than 5 years due to the condition changes of the environmental baseline studies and the data times series limits.

3.3. Calculation of monitoring cost

The monitoring cost is not influenced by the size of WWTP flow rate, but it is determined by the frequency of monitoring, the number of monitoring points, the monitored parameters, and the cost of sampling analysis for each sample in the laboratory. Accordance with monitoring practice on EIA studies in Indonesia, each WWTP is generally only monitored at three locations, namely: the influent quality before entering the WWTP, the effluent quality after leaving the WWTP, and the river water quality of WWTP effluent recipient. According to the regulations of the Ministry of Environment, effluent monitoring frequencies are set once in a month. The monitored parameters are adjusted to the applicable standards, such as BOD (Biological Oxygen Demand) and COD (Chemical Oxygen Demand). In 2014, the cost of sampling and laboratory analysis based on standards methods [16] for wastewater and river water in Surabaya city is 1,000,000 IDR per sample. Due to the fact that monitoring is accounted for 5 years (60 months) and the total monitoring points of every mall are at three locations, the total sample which is monitored will be 180 (60x3). The cost of sampling and laboratory analysis is 1,000,000 IDR (10^6 IDR) per sample so that the total cost of monitoring for each mall will be 180 x 10^6 IDR. In accordance with the Decree of the Minister of Environment No. 45/2005 [17], monthly monitoring has to be reported every six months by activity initiator.

3.4. Formulation of Linear Regression Equation

The formulation of linear regression equation employs Minitab 16 software tools. X axis represents the independent variable, which is the flow rate of wastewater from ten malls in l/sec, while Y axis represents the dependent variable, which is total cost of the WWTP from ten malls in IDRx10^6. Based on the results of DED, it was obtained the wastewater flow rate for ten malls in m^3/day. It was then converted into l/ sec. The total cost of each WWTP is the sum of the construction cost, the operation and maintenance cost, and monitoring cost. By processing all the independent and dependent variables from ten malls into Minitab 16 software, it would be obtained the results of the linear regression curve and the linear regression equation.

4. Results and Analysis

4.1. Flow rate of wastewater

Flow rate of wastewater in every mall in m^3/day was calculated from 70% water consumption on average each day. The daily water consumption on average was calculated based on the monthly average usage obtained from one year-water consumption record (January 2013 to December 2013). The flow rate of wastewater from ten malls in Surabaya city is shown in Table 1.

Table 1. Flow rate of wastewater from ten malls in Surabaya city

Mall	A	B	C	D	E	F	G	H	I	J
Flow rate (m^3/day)	77.08	114.28	122.63	126.35	181.84	214.94	235.65	355.41	528.22	587.03
Flow rate(l/sec)	0.88	1.31	1.41	1.44	2.08	2.46	2.70	4.06	6.03	6.72

Source: water demand mall 2013

It can be seen from Table 1 that the flow rate of wastewater for ten malls in Surabaya range from 0.88 l/sec to 6.72 l/sec. Ten variations of flow rate are considered sufficient to plot a regression curve and to formulate regression equation. Flow rate will serve as independent variable on the X axis of the graph of the regression curve.

4.2. Construction Cost

Total cost of this construction was calculated by the unit price of Surabaya City 2013 for construction activity groups i.e: preparatory work, soil work, concrete and foundation work, and finishing work, as shown in Table2.

Table 2. Total Cost of Construction

Mall	Preparatory Work (IDR)	Soil Work (IDR)	Concrete and Foundation Work (IDR)	Finishing Work (IDR)	Total Cost (IDR)	Total Cost (IDR x 10^6)
A	31,105,536	19,971,818	232,996,864	77,021,338	361,095,555	361
B	38,816,660	24,695,849	299,998,968	110,539,938	474,051,414	474
C	41,781,792	26,599,562	315,708,314	118,150,905	502,240,572	502
D	43,413119	27,628,245	326,043,129	121,444,338	518,528,831	519
E	54,435,201	34,318,455	428,740,491	171,040,678	688,534,826	689
F	63,071,184	39,788,927	480,764,888	200,799,490	784,424,489	784
G	60,640,722	47,478,930	512,465,720	219,121,556	839,706,927	840
H	79,498,624	61,636,882	696,061,625	326,459,914	1,163,657,045	1164
I	109,813,161	102,206,863	960,752,370	480,215,011	1,652,987,405	1652
J	117,492,768	109,047,094	1,044,179,715	532,617,675	1,803,337,253	1803

Source: unit price construction of Surabaya City in 2013

4.3. Total Cost

The calculation result from 10 malls in Surabaya City, which was obtained by the sum of construction, operation, maintenance, and monitoring cost, is shown in Table 3.

Table 3. Total cost of 10 malls in Surabaya city(in IDR x 10^6)

Mall	A	B	C	D	E	F	G	H	I	J
Construction Cost	361	474	502	519	689	784	840	1164	1653	1803
Operation and Maintenance Cost	36	47	50	52	69	78	84	116	165	180
Monitoring Cost	180	180	180	180	180	180	180	180	180	180
Total Cost	577	701	732	751	938	1042	1104	1460	1998	2163

Source: Unit Price of Surabaya Cityin 2013

The construction cost was taken from Table 2. Operation and maintenance cost was calculated at 10% of the construction cost in accordance with the description in section 3.2. Monitoring cost was calculated 180 x 10^6IDR for each mall as described in section 3.3. The monitoring cost of each mall was treated equal because there were only three monitoring locations for each mall i.e: the quality of the influent, effluent, and river water of effluent receiver.

4.4. Regression Curve

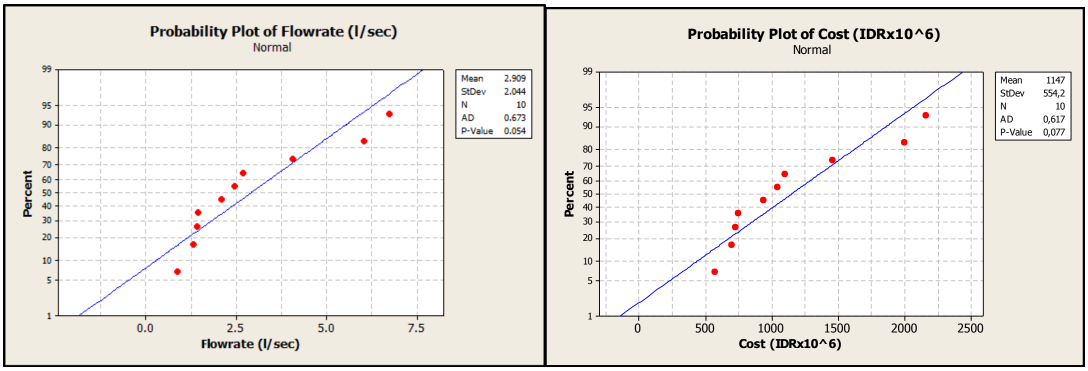
From the data in Table 1 and calculation from Table 3, the flow rate (independent variable) and total cost (dependent variable) for each mall can be seen in Table 4.

Table 4.Flow rate and Total Cost WWTP from ten malls in Surabaya city

Mall	A	B	C	D	E	F	G	H	I	J
Flow rate(l/sec)	0.88	1.31	1.41	1.44	2.08	2.46	2.70	4.06	6.03	6.72
Total Cost (IDRx10^6)	577	701	732	751	938	1042	1104	1460	1998	2163

Source : Table 1 and Table 3

By inputting the data in Table 4 to Minitab 16 software, the result can be seen in Fig. 1, Fig. 2, andFig. 3.



(a) (b)

Fig. 1.(a)Probability Plot of Flow rate; (b) Probability Plot of Cost

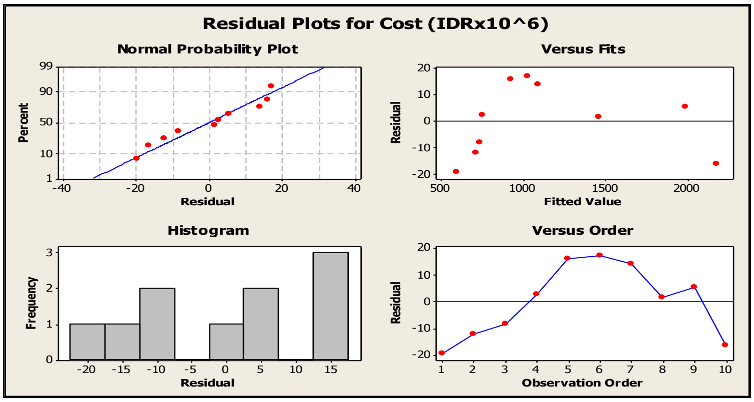


Fig. 2. Residual Plots for Cost

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Regression Analysis: Total Cost (IDRx10^6) versus Flowrate (l/sec)

The regression equation is
Total Cost (IDRx10^6) = 358 + 271 Flowrate (l/sec)

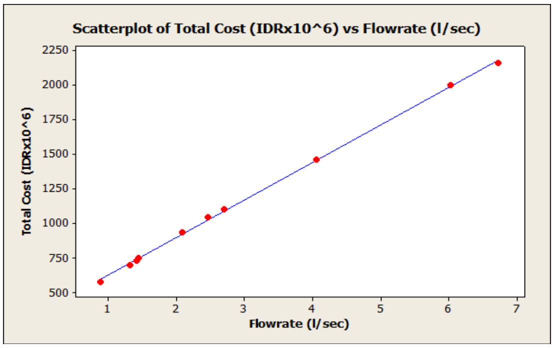

Predictor            Coef  SE Coef       T      P
Constant          358.151    8.226   43.54  0.000
Flowrate (l/sec)  271.038    2.353  115.20  0.000


S = 14.4275   R-Sq = 99.9%   R-Sq(adj) = 99.9%


Analysis of Variance

Source          DF       SS       MS         F      P
Regression       1  2762171  2762171  13270.00  0.000
Residual Error   8     1665      208
Total            9  2763836
```

(a)



(b)

Fig. 3(a) Regression Analysis; (b) Scatter plot of Cost vs Flow rate

Fig. 1 shows the plot probabilty of flowrate in X axis and total cost in Y axis. The two graphs show that the dispersion of the dots is close to diagonal line in which it can be concluded that the residual value is normal. In Fig.4, the residual plot of cost from Minitab 16 is depicted. The pictures abovepoint that ten data sets of X and Y produce reasonably good regression line with R-Sq = 99.9%. Generally, the more the date set, the better the regression[18]. From the regression analysis above, the linear regression curve has been obtained and shown in Fig. 3 with the regression equation of Y = 358 + 271X , where Y represents cost inmillion Indonesian Rupiah (IDR x 10^6) while X represents flow rate in litre/second.

4.5. Discussion

The result of linear regression equation has improved the linear regression equation from the previous studies [3.4] where the Y axis was the construction costs only. In this case study, the Y axis includesnot only the construction costs but also the operation and maintenance costand monitoring costs in accordance with the WWTP cost in the EIA study.

The linear regression equation of Y = 358 + 271X can be used to quickly predict the WWTP total cost by entering all the flowrate value ranging from i.e.1 l/sec to 19 l/sec, as shown in Table 5.

Table 5 Prediction of WWTP total cost (Y) from WWTP flow rate (X) using equation Y = 358 + 271 X

Flow rate (l/sec)	1	3	5	7	9	11	13	15	17	19
Total Cost (IDRx10^6)	629	1171	1713	2255	2797	3339	3881	4423	4965	5507

Source : Fig. 3

Table 5 illustrates that the higher the flow rate, the higher prediction WWTP total cost. It is influenced by the flow rate increase. The monitoring costs did not significantly affect the prediction total cost of WWTP. The flow rate conversion from 1/sec to m^3/day can be seen in Table 6.

Table 6 Prediction cost of WWTP with the flow rate conversion from l/sec to m^3/day

Flow rate (l/sec)	1	3	5	7	9	11	13	15	17	19
Flow rate (m^3/day)	86.4	259.2	432	604.8	777.6	950.4	1123.2	1296	1468.8	1641.6
Total Cost (IDRx10^6)	629	1171	1713	2255	2797	3339	3881	4423	4965	5507

Source: Table 5

The prediction results in Table 5 and Table 6 can be directly applied by the EIA committee in Surabaya city and activity initiator to decide the environmental feasibility of a mall based on the predicted cost of WWTP.

5. Conclusion

The result of the study shows that the linear regression curve between flow rate WWTP (as independent variable in the X-axis) and the total cost of WWTP (as dependent variable in the Y-axis) has resulted in a linear regression equation of $Y = 358 + 271X$.The linear regression equation can be directly used by the EIA committee in Surabaya city and activity initiator to decidethe environmental feasibility of a mall based on the predicted cost of WWTP.

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