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FORMULA FOR PREDICTING MATERIAL NEEDS IN RESIDENTIAL BUILDING PROJECTS

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ABSTRACT

Residential development projects require resources and resource management is the most important factor in project success. Resources needed in residential building projects are money, materials, manpower, machinery and methods. Improper management of resources will result in project delays and losses. Every construction project requires material resources and if it is not appropriate to provide material, construction project completion will be too late. Delay in the completion of a construction project that often occurs is the result of inadequate in providing material, this happens because they do not know exactly how much material is needed. Estimation method for predicting material needs in existing construction projects so far there needs to be complete data, through a long process and requires special expertise, therefore often it is not appropriate to provide material. Based on the description of this problem, then how to predict the material needs of residential building projects when data information is limited. Can it be predicted the amount of all material needs if there is only information on the area of the planned residential building. To solve this problem the solution is a model. This model is a formula for predicting material needs. This model is the result of research using the Regression Analysis (RA) method using 100 sampling data and this data is the data on the amount of material used in residential building projects. The model is then arranged in the application, then becomes a program. Using this model, only entering the planned residential building area data, then automatically 24 types of items in the housing construction project will be predicted. This model has an average difference of under 5% so that it can be stated this model can be used to predict the amount of material needs in residential building projects accurately, easily and quickly.

Keywords: estimation formula, predict material quickly, project material requirements, residential construction, regression analysis.

INTRODUCTION

Residential development projects require resources and resource management is the most important factor in project success. Resources needed in residential building projects are money, materials, manpower, machinery and methods. Improper management of resources will lead to cost overruns (Manto, 2016) and proper management of resources can save considerable construction costs (Shehata *et al*, 2012).

Construction of residential houses is always done to meet the needs of human habitation ((Giannett *et al*, 2017). In the process, housing construction projects are often encountered which are delayed in completion, even stalled. Every construction project must use equipment and materials (El-halek *et al*, 2018) and delays in construction projects often occur due to improperly providing materials (Wang and Hubbard 2017), this happens because they do not know how much material must be provided (Astana, 2007) and (Limbong *et al*, 2013). Therefore, it is necessary to plan simultaneously related to the supply of materials, because it greatly affects the economic performance of construction projects (Jaśkowski *et al*, 2018).

Based on these problems, it is very important to know the amount of material needs in construction projects before carrying out construction, to anticipate delays in construction projects due to inaccurate supply of material (Wang and Hubbard 2017). The method for estimating material needs so far can be done using the *Burgeslijke Openbare Werken* (BOW) method and in Indonesia it has been updated to the analysis of the Indonesian National Standard (SNI), (Paikun *et al*, 2017), the BIM application method called zgBIMs (Wei *et al*, 2017), the MRP method SNI (Astana, 2007), and (Limbong, 2013). The method of estimating material needs as stated by previous research is no doubt the truth, but the methods can be used to estimate material needs in construction projects if supported by complete data information.

For example, the data information that must be available to be able to estimate material requirements using the BOW method, there must be a detailed design drawing, from the detailed design drawings examined and then producing a bill of quantity, from a bill of quantity then analyzed to determine material requirements, labor and equipment, then can only be predicted the material needs, labor and tools based on work items, then subsequently recap the amount of each material requirement. After going through the stages of this process, only then can the total amount of material needs be predicted. Through this stage of the process and data requirements, the material needs of the construction project can be predicted using the BOW method, as well as the same illustration to predict the material needs of the construction project using the BIM application method and the MRP method, requiring special expertise and requires considerable time.

The tendency of not precisely preparing material requirements for contractors (Wang and Hubbard 2017) was then stated because they did not know how much

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material had to be provided (Astana, 2007) and (Limbong, 2013), it should be suspected because the method for predicting the amount of material needs requires complete data , requires special expertise and requires a long process. In addition to this tendency, the phenomenon of rural communities in Indonesia, to provide a place to live, is largely done independently. To build a place to live, rural communities in Indonesia, the first step is to collect material needs little by little, until finally it is estimated that the material is complete, then start building the house. Based on these predictions, it is often inappropriate to prepare material needs, sometimes lacking and sometimes too much.

Based on the description of this problem, it is necessary to have a simple formula, to predict the amount of material needs in housing construction projects. This formula must function even with very limited information, for example there is only information on the area of a planned building, therefore this research becomes very important to produce this simple formula. Using the formula that will be generated in this study, only by knowing the area of the planned residential building, all material requirements can be predicted.

RELATED WORK

Construction materials that are not available for installation cause delays in construction projects and pose a risk to overall project delays. Supply chain performance in construction projects, focusing on steel coils and structural pipes that are often used in construction projects. In his review it was found that there were many possible delays, missing and damaged parts, overall 22% for structural steel and 18% for pipe coils. New technologies such as RFID will be a possible way to improve the supply chain process of construction projects, (Wang and Hubbard 2017).

To anticipate project delays, most construction contractors prefer to outsource construction project activities to subcontractors. The pre-qualification process for subcontractor selection is one of the main and very main processes. The selection of subcontractors is grouped into seven priority groups. Five of the seven criteria evaluated were determined as the most influential: 1) Timely delivery of materials; 2) Failure to complete the contract due to financial problems; 3) Difficulties of subcontractors in replacement; 4) Reputation; 5) Tender Prices (Hesham *et al.* 2018).

To explore and confirm strategies for achieving efficient waste material procurement in construction activities, use a sequential exploratory mixed method approach as a methodological framework, using focus group discussions, statistical analysis, and structural equation modelling. This method reinforces waste management practices at another stage of the material delivery process at the project (Saheed *et al*, 2018).

Calculating material requirements in housing construction is very important, to overcome the problem of budget inaccuracies, lack of comprehensive or high-level management, and the presence of remaining material during the construction phase. BIM-based method is a solution to calculate the material needed for housing construction (Wei *et al,* 2017).

Construction practitioners and researchers have developed a four-dimensional (4D) model by connecting the three-dimensional (3D) component of the building information model (BIM) with the network activities of the project schedule. Operating simulations can consider the duration of work assignments that are uncertain, allowing them to consider the competing needs for resources among several work tasks, and to evaluate various resource allocation strategies, thus creating a development plan that is generated and linked to the 3D BIM component. (Wang *et al*, 2014).

METHODOLOGY

This research uses quantitative descriptive methods and is supported by project document data. Random sampling data in this study, as much as 100 data consisting of construction work drawings data, bill of quantity data, data on the budget plan for housing projects that have been completed and the data on material usage on housing projects.

Work drawings data are analyzed to identify the building area, building components and types of work, as well as the volume of each building component. Then the data is processed using the *Burgeslijke Openbare Werken* (BOW) method, to determine the amount of material requirements based on the volume of each job. After having recorded the total material needs, grouped according to the area of each building. This data then becomes part of the data for statistical regression analysis (Nurjannah *et al,* 2019).

Bill of quantity data is a project document. From this data analyzed to find out the amount of material needs, according to the area of each building. The results of this data analysis process become part of the data for regression analysis.

Cost budget plan data is a very confidential project document, from this data analyzed to find out the amount of material needs, according to the area of each building. The results of this data analysis process become part of the data for regression analysis.

Material usage data on housing projects are confidential documents of the contractors. Data on material usage is classified based on building area. The material referred to in this study consisted of 24 types namely; foundation stone, cement, sand, gravel, brick, ceramics, 8 mm concrete reinforcement steel, 12 mm concrete reinforcement steel, mild steel C channel, mild steel lath, roof tiles, roof ridge, planks, hollow steel, gypsum PVC pipe 4 ", PVC pipe 3", PVC pipe ¾ ", PVC pipe ½", 2x1.5 mm cable, lamp fitting, switch, stop contact and paint.

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Data Collection Technique

Data collection in this study includes work drawings, bill of quantity and housing development budget plan, obtained directly from the contractor or project implementer, while material usage data, besides obtained from the contractor, is also obtained by observation and direct recording of material usage on the project residential construction.

Residential Building Type

The type of residential building that is the object of this research is a type of residential building with a modern minimalist design, consisting of one-story buildings and two-story buildings with the smallest building area of 21 m^2 and the largest of 290 m^2. Housing development projects that are the object of research are housing projects that are mass-built by developers and contractors, as well as housing projects that are built independently by individuals. Type of modern minimalist house building as an illustration, as shown in Figure-1 for one-story buildings and Figure-2 for two-story house buildings.

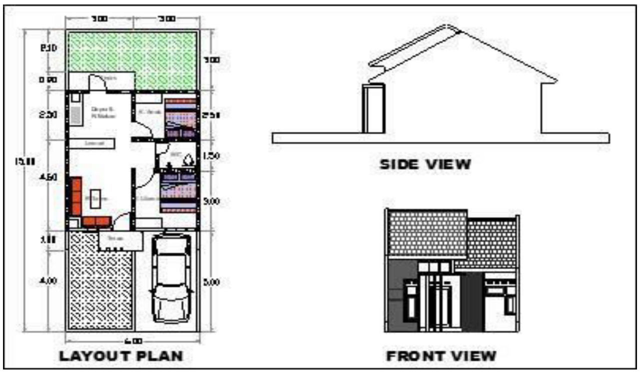

Figure-1. Examples of research objects one-story house.

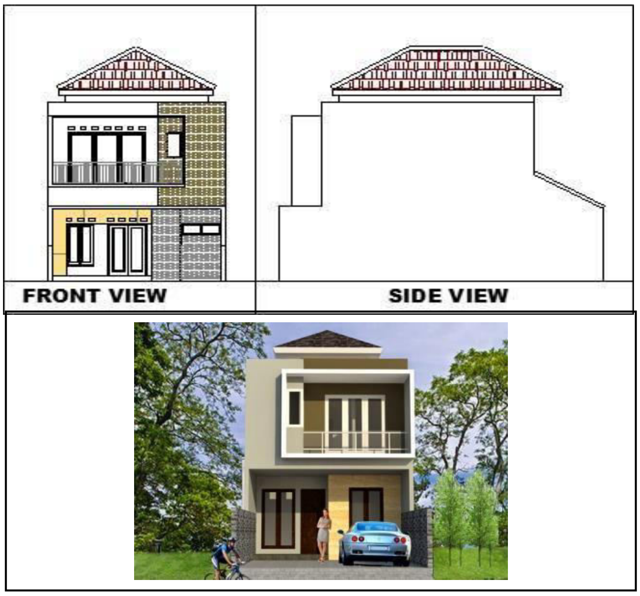

Figure-2. Examples of research objects two-storey house.

Data Analysis

Data on the use of materials that have been classified based on the area of the building then becomes the variables in the regression analysis. The decision variable is determined, the materials as the dependent variable are expressed as the Y variable, and the building area as the independent variable is stated as the X variable. Because the dependent variable (Y) consists of 24 types of material, it was subsequently decided that foundation stone as (Y_1), cement (Y_2), sand (Y_3), gravel (Y_4), brick (Y_5), ceramics (Y_6), 8 mm concrete reinforcement steel (Y_7), 12 mm concrete reinforcement steel (Y_8), C channel mild steel (Y_9), mild steel lath (Y_{10}), roof tiles (Y_{11}), roof ridge (Y_{12}), planks (Y_{13}), hollow steel (Y_{14}), gypsum (Y_{15}), PVC pipe 4" (Y_{16}), PVC pipe 3" (Y_{17}), PVC pipe ¾ "(Y_{18}), PVC pipe ½" (Y_{19}), 2x1.5 mm cable (Y_{20}), lamp fittings (Y_{21}), switches (Y_{22}), stop contacts (Y_{23}) and paint (Y_{24}).

As many as 24 kinds of materials are technical specifications that are often used in housing construction in Indonesia so that in this study the focus is on the material specifications recorded in this study.

The initial stage of data analysis is the data normality test. Test data normality to find out whether the data distribution is normal or not. After knowing the distribution of data with normal distribution, then the correlation test is performed. The correlation test aims to find out how big is the correlation of variable X to variable Y. Then a significance test is performed to determine whether the X variable significantly influences the Y variable. After that, do the model summary test and ANOVA test to find out the value of R square, F table, and T table (Zhang *et al*, 2019). Then test the coefficient to get the value of parameter Y and the value of parameter X as a model. After getting the model then the model validation test is carried out to determine the accuracy of the model and after the model is declared can be used to predict the number of material needs, then the model is then compiled in application to become a simple program, to predict the amount of material needs in a housing construction project.

This program is prepared using the excel application, by:

1. Arrange the names of the ingredients in the first column of row 1 to completion,
2. Fill in each material model in the second column according to the material name in question,
3. To detect the amount of material automatically, the model must be connected to one of the rows of columns prepared to enter the building area prediction data in the excel program table.

Research Flow

Stages of research to produce models and programs, as a formula for estimating the number of materials needs in housing construction projects in this study, can be briefly explained in a research flowchart such as Figure-3.

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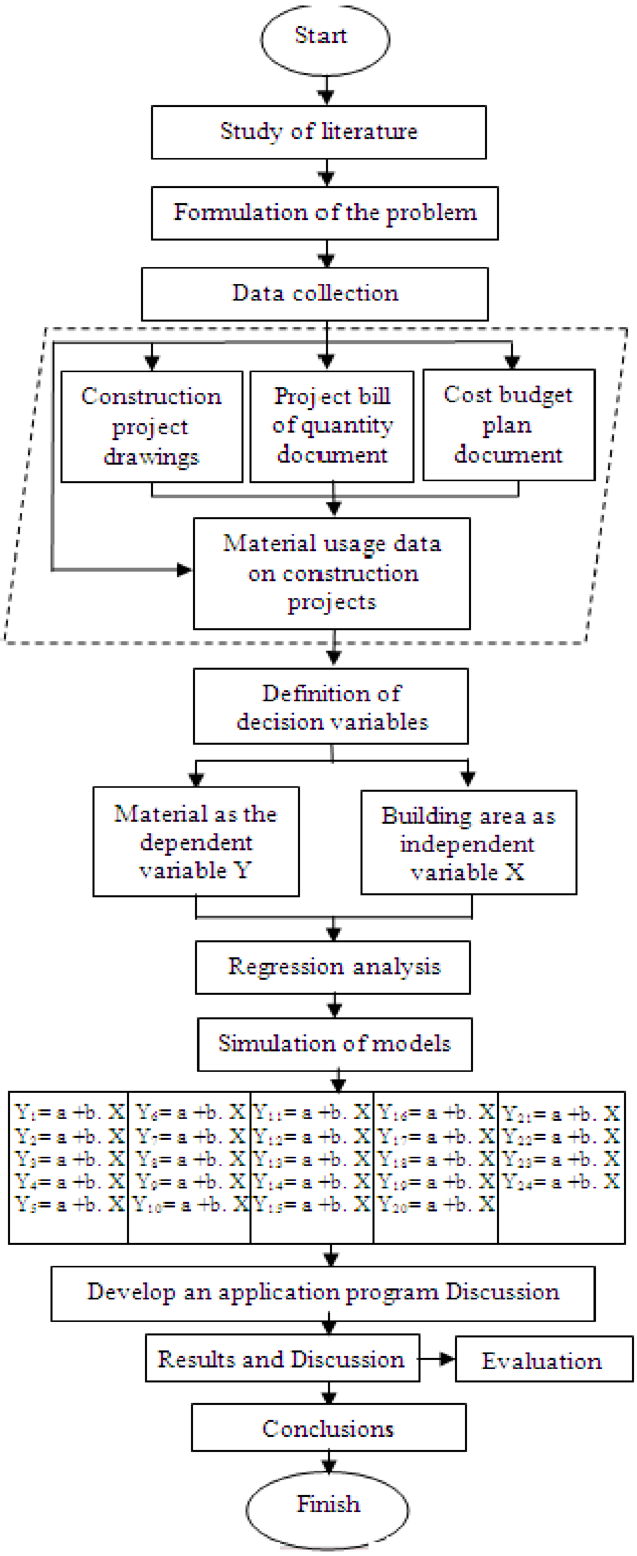

Figure-3. Research flowchart.

RESULTS AND DISCUSSIONS

Research Data

The research data consisted of project drawings, bill of quantity, budget plans and material data used in housing construction consisting of 100 random sampling data. Before doing a statistical analysis to produce a model, this data is first processed into dependent variables and independent variables. The decision was made that material needs in housing construction as the dependent variable and building area as independent variables. To produce predetermined variables, the data is processed with different stages depending on the type of data.

Data type 1 (housing construction image), processed by analyzing the image into a bill of quantity, then analyzing the material requirements needed, using the *Burgerlijke Openbare Werken* (BOW) method. Data type 2 (bill of quantity) is analyzed to determine the material requirements needed using the BOW method. Data type 3 (cost budget plan) is processed using the BOW method to determine the amount of material needed. Data type 4 (use of material in housing projects) is classified based on the name of the material and the amount of material based on the area of each building. Process data types 1-3, resulting in the same grouping of data as data type 4 (use of materials in housing projects).

Process Data Type 1 (Construction Drawing)

Data type 1 is derived from construction drawings, consisting of 10 random sampling data. The first processing is calculating the volume of work (building components) based on work items and grouped according to building area. The volume and extent of work items that are calculated in accordance with the components of the house building listed in the image include, among others; foundation, wall, concrete structure (foundation, tee beams, columns, beams, floor plates, stairs, wall tie beams, girders), roof, ceiling, floor, door frame, window frame, mechanical electrical, sanitary, painting, etc. This data processing flow is briefly explained in Figure-4.

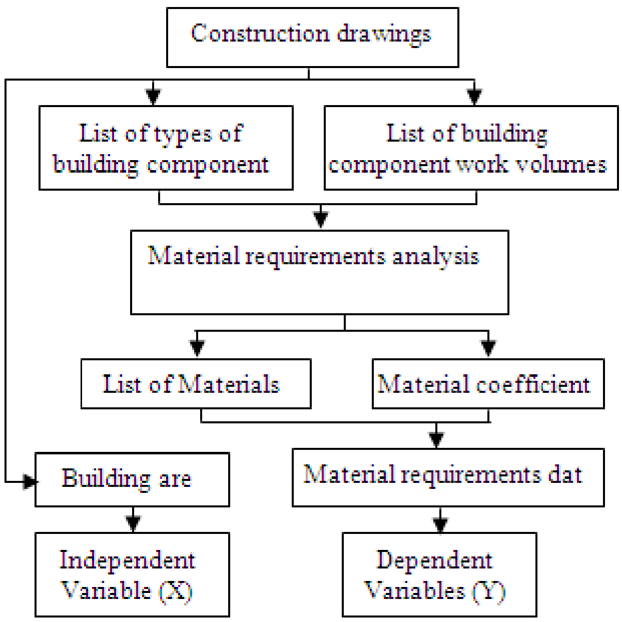

Figure-4. Process flow type 1 data.

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Process Data Type 2 and Data Type 3

Data type 2 (bill of quantity) and data type 3 (budget plan) each consists of 10 random sampling data, processed using the BOW method. From these two types of data, the types of work (building components) and the area of each building have been detailed, and then analyzed to determine the amount of material needed. The data analysis scheme is the same as described in Figure-4, but there is no need to analyze the image.

Analysis of the amount of material needed in housing construction using the BOW method is by multiplying the coefficient determined by the BOW method with the volume of work. As an illustration of how to calculate the material requirements referred to are explained in Table-1.

Table-1. Examples of material analysis required for wall work.

Material description	Unit	Coefficient	Volume of concrete structure	Amount of material
a	b	c	d	c *x* d
Cement	Kg	323	80	25,840.00
Sand	M^3	0.52		41.60
Gravel	M^3	0.78		62.40

Based on the BOW method it is known that concrete works consist of materials and coefficients; cement coefficient 323 kg, sand coefficient 0.52 m^3 and gravel coefficient 0.78 m^3. This coefficient is to produce concrete in a volume of 1 m^3. Based on the example in Table 1 the concrete volume is 80 m3, after the volume of the concrete is multiplied by the multiplier factor coefficient of each material, it can be seen that the material needed is; cement 25,840.00 kg, sand 41.60 m^3 and gravel 62.40 m^3.

Other types of work (building components) are analyzed and calculated the same as calculating concrete work. Through this process, data types 1-3 can be analyzed and the amount of material needed can be determined, according to the building area of each data. The results of this process are further grouped by the amount of material needed for each house construction based on the area of each building.

Data Type 4 (Use of Material in Housing Construction)

Data type 4 consists of 70 data is data on the use of materials in housing construction projects.

This type of data does not need to be analyzed using the BOW method such as data type 1-3, but to get this type 4 data through a long process, namely through direct observation and recording on the housing construction project being carried out.

Data types 1-4 eventually become the same data type, namely data on the amount of use of materials in residential construction projects. These four data types are needed as random sampling data. This data is then analyzed statistically using the method of regression analysis. Examples of process data results consisting of 1-4 data types are exemplified in Table-2.

Table-2. Examples of material data resulting from processing data types 1-4.

N	Build. area (m^2)	Sand (m^3)	Gravel (m^3)	Cement (kg)	Brick (pcs)	Concrete steel 12 mm (kg)
	a	1	2	3	4	5
1	55	39	11	11,766	19,212	1,590
2	70	47	14	14,592	22,506	2,090
3	70	43	14	13,557	19,384	2,081
4	94	58	19	18,253	26,372	2,824
5	69	44	12	13,348	21,805	1,758

Data such as the example in Table-2 consists of 100 data and consists of 24 types of material namely; foundation stone, cement, sand, gravel, brick, ceramics, 8 mm concrete reinforcement steel, 12 mm concrete reinforcement steel, C channel mild steel, mild steel lath, roof tiles, roof ridge, planks, hollow steel, gypsum, PVC pipe 4 ", PVC pipe 3", PVC pipe ¾ ", PVC pipe ½", 2x1.5 mm cable, lamp fittings, switches, stop contacts and paint Building area data then becomes free variable data (X) and material data becomes dependent variable (Y). Because the dependent variable (Y) consists of 24 types of material, then the dependent variable (Y) is determined; foundation stone (Y_1), cement (Y_2), sand (Y_3), gravel (Y_4), brick (Y_5), ceramics (Y_6), 8 mm concrete reinforcement steel (Y_7), 12 mm concrete reinforcement steel (Y_8), C mild steel channel (Y_9), mild steel lath (Y_{10}), roof tiles (Y_{11}), roof ridge (Y_{12}), planks (Y_{13}), hollow steel (Y_{14}), gypsum (Y_{15}), PVC pipe 4" (Y_{16}), PVC pipe 3 "(Y_{17}), PVC pipe ¾" (Y_{18}), PVC pipe ½" (Y_{19}), 2x1.5 mm cable (Y_{20}), lamp fittings (Y_{21}), switches (Y_{22}), stop contacts (Y_{23}) and paint (Y_{24}).

These data are the variables which then become regression analysis data to produce a model (Chithra *et al*, 2016). The data analysis variables as exemplified in Table-3.

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Table-3. Examples of data analysis variables.

Independent variable (X)	Dependent variable (Y)			
Build. area (m2)	**Foundation stone (m3)**	**Sand (m3)**	**Gravel (m3)**	**Cement (kg)**
Variable X	Variable Y_1	Variable Y_2	Variable Y_3	Variable Y_4
55	5	39	11	11,766
70	6	47	14	14,592
70	6	43	14	13,557
94	7	58	19	18,253
69	6	44	12	13,348
99	7	59	16	17,856
61	10	64	39	25,281
76	9	67	36	24,909
109	57	83	18	24,529
40	12	33	9	10,052
72	5	52	15	15,986
286	150	85	52	33,833
88	45	40	28	16,730
234	140	123	23	34,526
211	132	141	27	41,289

Variable data as in the example of Table-3 consists of 100 data and consists of 24 dependent variables, starting from Y_1 (foundation stone) to the last Y_{24} (paint). Random sampling data consists of 10 data types 1, 10 data types 2, 10 data types 3 and 70 data types 4.

Regression Analysis

Regression analysis aims to produce a model. To get a model must go through the analysis phase. The first analysis is the normality test of data to find out whether the data can be normally distributed or not. If the data is normally distributed, then it can be further analyzed. The data normality test uses probability plots (Das and Imon, 2016). For example, the normality of data on the dependent variable Y_4 (cement) is shown in Figure-5.

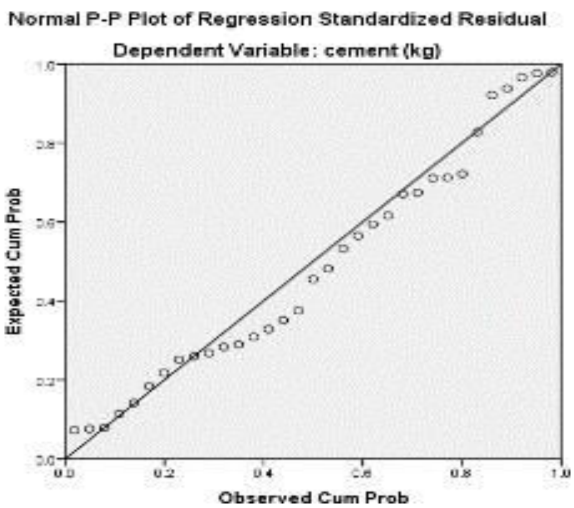

Figure-5. Example of data normality test at Y_{24} (cement).

The basis for decision making for the normality test of the plot probability method, if the data spreads along the diagonal line then the data is declared to be normally distributed, but if the data spread does not follow the diagonal line, then the data is not normally distributed. Example of normality test data on the dependent variable or Y_4 (cement), the spread of the data follows a diagonal line, this means the data is normally distributed. Data normality test is done one by one starting from the first dependent variable, Y_1 (foundation stone), up to the last variable, Y_{24} (paint). The results of this data normality test, all meet the data normality test requirements.

The next step is the correlation test which aims to find out how big is the correlation of variable X to the variable Y, (Gagné 2014). For example, the results of the analysis of the correlation of variable X (building area) to variable Y_{16} (PVC pipe 4") are shown in Table-4.

Table-4. Example of correlation analysis of variable X (building area) to variable Y_{16} (PVC pipe 4").

Correlations			
		PVC 4" (rod)	**Building area**
Pearson Correlation	PVC pipe 4" (rod)	1.000	1.000
	Building area	1.000	1.000
Sig. (1-tailed)	PVC pipe 4" (rod)		.000
	Building area	.000	
N	PVC pipe 4" (rod)	100	100
	Building area	100	100

Correlation test results as shown in Table-4, means that the variable Y_{16} (PVC 4") correlates 100% to the variable X (building area), as well as the variable X (building area) correlated by 100% to the variable Y_{16} (PVC 4").

The results of the overall correlation test between variable X (building area) and variables Y (Y_1 - Y_{24}) are summarized in Table-5.

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Table-5. Summary of correlation test results.

Pearson Correlations	
Variable Y	**Variable X (build. area)**
Y_1 = foundation stone (m^3)	0.431
Y_2 = cement (kg)	0.882
Y_3 = sand (m^3)	0.879
Y_4 = gravel (m^3)	0.730
Y_5 = brick (pcs)	0.855
Y_6 = ceramics (m^2)	0.969
Y_7 = 8 mm concrete steel (kg)	0.726
Y_8 = 12 mm concrete steel (kg)	0.726
Y_9 = C mild steel channel (rod)	0.735
Y_{10} = mild steel lath (rod)	0.734
Y_{11} = roof tiles (pcs)	0.735
Y_{12} = roof ridge (pcs)	0.735
Y_{13} = planks (sheet)	0.735
Y_{14} = hollow steel (rod)	0.975
Y_{15} = gypsum (sheet)	0.975
Y_{16} = pvc pipe 4” (rod)	1.000
Y_{17} = pvc pipe 3” (rod)	1.000
Y_{18} = pvc pipe ¾” (rod)	1.000
Y_{19} = pvc pipe ½” (rod)	1.000
Y_{20} = 2x1.5 mm cable (roll)	1.000
Y_{21} = lamp fittings (roll)	1.000
Y_{22} = switches (unit)	1.000
Y_{23} = stop contacts (unit)	0.999
Y_{24} = paint (kg)	0.958

The next analysis is the R square test, the significance test and the Durbin-Watson test (D-W). R square test to find out how much the independent variable (X) can explain the dependent variable (Y), (Quessy. 2019). The significance test aims to find out whether the independent variable (X) significantly influences the dependent variable (Y). Durbin-Watson Test (D-W) aims to determine the existence of autocorrelation (Proïa. 2013). The interpretation of R square is that the number contained in R square can explain the dependent variable (Y) in accordance with the value that is in R square. For example, the value of R square is 0.910, meaning that the independent variable (X) can explain the dependent variable (Y) of 91%. Significance test interpretation is, if the value of significance test results < 0.05 then the independent variable (X) significantly influences the dependent variable (Y), but if the significance test value > 0.05 then it means, the independent variable (X) does not significantly affect the dependent variable (Y). Interpretation of the Durbin-Watson test (D-W) if the D-W test value < - or + 2.00 then the data does not occur autocorrelation, but if the value of D-W > - or + 2.00 then the data occurs autocorrelation. Testing all of this can be done using the Model Summary method. Summary method. The results of the R square test analysis, the significance and the Durbin-Watson test (D-W), are summarized in Table-6.

Table-6. Summary of test results for the Model Summary method.

N	Model	R	Sig. F Change	Durbin-Watson (D-W)
1	Y_1	0.431	0.012	1.462
2	Y_2	0.882	0.000	1.803
3	Y_3	0.879	0.000	2.038
4	Y_4	0.730	0.000	1.784
5	Y_5	0.855	0.000	2.682
6	Y_6	0.969	0.000	1.723
7	Y_7	0.726	0.000	1.784
8	Y_8	0.726	0.000	1.784
9	Y_9	0.735	0.000	1.672
10	Y_{10}	0.734	0.000	1.678
11	Y_{11}	0.735	0.000	1.674
12	Y_{12}	0.735	0.000	1.688
13	Y_{13}	0.735	0.000	1.672
14	Y_{14}	0.975	0.000	1.617
15	Y_{15}	0.975	0.000	1.616
16	Y_{16}	1.000	0.000	1.936
17	Y_{17}	1.000	0.000	1.592
18	Y_{18}	1.000	0.000	1.811
19	Y_{19}	1.000	0.000	2.415
20	Y_{20}	1.000	0.000	1.581
21	Y_{21}	1.000	0.000	2.127
22	Y_{22}	1.000	0.000	1.909
23	Y_{23}	0.999	0.000	1.843
24	Y_{24}	0.958	0.000	2.166

After going through the testing stages as outlined above, the coefficient method analysis is then performed, in order to produce the Y intercept and the X constant, (Lei He and Daojiang He. 2020). Intercept Y and this X constant, hereinafter referred to as the model, and this model can then be used to predict the amount of material needed in housing construction projects. The results of the coefficient test and the model produced in this study are further summarized in Table-7.

Table-7. Summary of coefficient and model test results.

Symbol	Y Intercept	X Constant	Model
Y	a	b	Y = a + b. X
Y_1	2.09	0.14	Y_1 = 2.09 + 0.14.X
Y_2	3,629.83	129.08	Y_2 = 3,629.83 + 129.08.X
Y_3	12.96	0.4	Y_3 = 12.96 + 0.40.X
Y_4	2.43	0.13	Y_4 = 2.43 + 0.13.X
Y_5	7,059.32	148.87	Y_5 = 7,059.32 + 148.87.X
Y_6	0.45	1.07	Y_6 = 0.45 + 1.07.X
Y_7	898.93	45.11	Y_7 = 898.93 + 45.11.X
Y_8	382.87	19.21	Y_8 = 382.87 + 19.21.X
Y_9	37.32	0.46	Y_9 = 37.32 + 0.46.X
Y_{10}	56.14	0.69	Y_{10} = 56.14 + 0.69.X
Y_{11}	673.47	8.34	Y_{11} = 673.47 + 8.34.X
Y_{12}	17.92	0.22	Y_{12} = 17.92 + 0.22.X
Y_{13}	37.06	0.46	Y_{13} = 37.06 + 0.46.X
Y_{14}	20.33	1.43	Y_{14} = 20.33 + 1.43.X
Y_{15}	20.33	1.43	Y_{15} = 20.33 + 1.43.X
Y_{16}	0.06	0.27	Y_{16} = 0.06 + 0.27.X
Y_{17}	-0.13	0.45	Y_{17} = - 0.13 + 0.45.X
Y_{18}	0.2	0.3	Y_{18} = 0.20 + 0.30.X
Y_{19}	-0.13	0.34	Y_{19} = - 0.13 + 0.34.X
Y_{20}	-0.09	2	Y_{20} = - 0.09 + 2.00.X
Y_{21}	-0.02	0.2	Y_{21} = - 0.02 + 0.20.X
Y_{22}	0.09	0.13	Y_{22} = 0.09 + 0.13.X
Y_{23}	-0.16	0.12	Y_{23} = - 0.16 + 0.12.X
Y_{24}	2.09	0.14	Y_{24} = 2.09 + 0.14.X

The results of the coefficient analysis have produced as many as 24 models, to predict the amount of material needed in a residential construction project. The input variable in the model is variable X (building area), so that in order to predict the amount of material needed in a housing construction project, it only requires information on planned housing area data.

How to Use a Model

To predict the amount of material needed for a home construction project, from now on it becomes easy because there is a model of the results of this research. How to predict it is, use the model and input the planned building area. For example, it is known that the planned area of a building is 70 m^2, how much cement is needed. Using a model, it can be predicted using equation Y_2.

Y_2 = 3,629.83 + 129.08.X

Y_2 = 3,629.83 + 129.08 *x* 70

Y_2 = 12,665.43

Using the model, it can be predicted that the amount of cement material needed to construct a house with an area of 70 m^2 is 12665.43 kg or equal to 253.31 sacks of cement with a capacity of 50 kg.

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Model Validation Test

The models of the results of this study are then tested for validity, to determine the accuracy of the model. The way to test it is to compare the amount of material needed for a home construction project with a certain building area, between the model and the factual, (Muñoza et al, 2019). To calculate the percentage difference between the model and the factual can be calculated by:

$$\text{percentage difference} = \frac{\text{model}-\text{factual}}{\text{model}} x100$$

The model validation test is exemplified here on the Y_2 (cement) model, on a building area of 55 m^2, 70 m^2, 102 m^2, 234 m^2 and 290 m^2. The model validation test is exemplified in Table-8.

Table-8. Examples of model validation tests.

Build. Area	Cement material, which is needed		
	Y2 Model	Factual	Difference%
a	b	c	(a-b)/bx100
55	10,729	11,766	-10%
70	12,665	13,557	-7%
102	16,796	16,887	-1%
234	33,867	34,526	-2%
290	41,063	40,524	1%
Difference in average percentage			-4%

Validation test on model Y_2, for different building area, there is a difference between 1% - 10% and the average difference is -4%. Predicting the amount of cement material needed in housing construction projects using the model, the results are less than the factual, meaning that this model can be used and will not experience excess material that can cause losses. The models produced in this study are feasible to use, because there is only an average difference of 4%.

All models produced in this study have passed the validation test and the results are good, on average there is a difference below -5%, except for stone foundations that have a difference of -12%. After passing the model validation test, the model is then compiled in the Microsoft Excel program, so that it is easier to predict the amount of material needed in a housing construction project.

Making Application Program

Making the application program referred to in this study, using Microsoft Excel applications. The reason for using the Microsoft Excel application, is that in general people in Indonesia can use it. Create an application in Microsoft Excel, with the following steps:

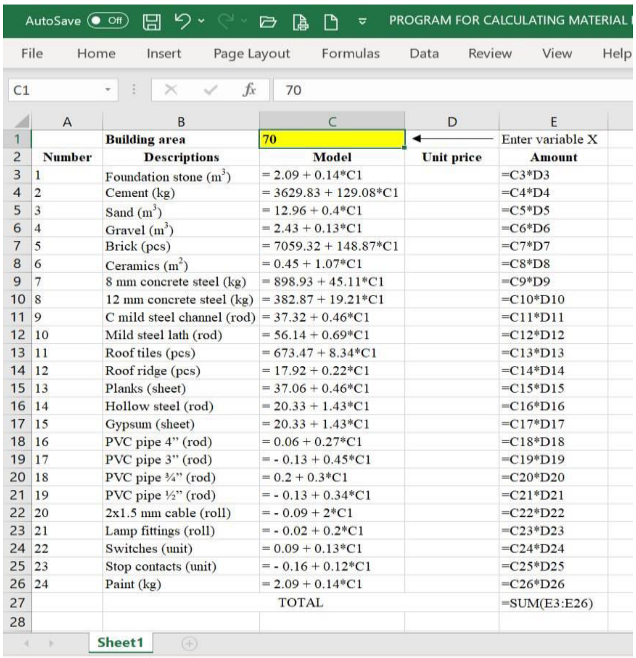
a) In row 1 column B, write the building area and row 1 column C, enter the building area data.

b) In row 2 column A write Number, in row 2 column B write Descriptions, in row 2 column C write Model. If you want to calculate material costs, then in row 2 column D write the unit price and in row 2 column E write Amount.

c) In row 3 column A write 1, in row 3 column B write Foundation stone (m^3), in row 3 column C write = 2.09 + 0.14 * C1 (model Y_1), in row 3 column D enter the price of foundation stone / m3 or for example 250,000 and in row 3 write column E write = C3 * D3.

d) In row 4 enter the same thing as stage 3, which is entering the material serial number, material name, model, material price and total. Enter all in the next row as in stage 3 starting at Y_2 - Y_{24}.

After all the models have been included in the Microsoft Excel application, in accordance with the stages presented in this study, the making of a program to predict the material needed for a home construction project is complete. Making this application program as shown in Figure-6.



	A	B	C	D	E
1		Building area	70	←	Enter variable X
2	Number	Descriptions	Model	Unit price	Amount
3	1	Foundation stone (m^3)	= 2.09 + 0.14*C1		=C3*D3
4	2	Cement (kg)	= 3629.83 + 129.08*C1		=C4*D4
5	3	Sand (m^3)	= 12.96 + 0.4*C1		=C5*D5
6	4	Gravel (m^3)	= 2.43 + 0.13*C1		=C6*D6
7	5	Brick (pcs)	= 7059.32 + 148.87*C1		=C7*D7
8	6	Ceramics (m^2)	= 0.45 + 1.07*C1		=C8*D8
9	7	8 mm concrete steel (kg)	= 898.93 + 45.11*C1		=C9*D9
10	8	12 mm concrete steel (kg)	= 382.87 + 19.21*C1		=C10*D10
11	9	C mild steel channel (rod)	= 37.32 + 0.46*C1		=C11*D11
12	10	Mild steel lath (rod)	= 56.14 + 0.69*C1		=C12*D12
13	11	Roof tiles (pcs)	= 673.47 + 8.34*C1		=C13*D13
14	12	Roof ridge (pcs)	= 17.92 + 0.22*C1		=C14*D14
15	13	Planks (sheet)	= 37.06 + 0.46*C1		=C15*D15
16	14	Hollow steel (rod)	= 20.33 + 1.43*C1		=C16*D16
17	15	Gypsum (sheet)	= 20.33 + 1.43*C1		=C17*D17
18	16	PVC pipe 4" (rod)	= 0.06 + 0.27*C1		=C18*D18
19	17	PVC pipe 3" (rod)	= - 0.13 + 0.45*C1		=C19*D19
20	18	PVC pipe ¾" (rod)	= 0.2 + 0.3*C1		=C20*D20
21	19	PVC pipe ½" (rod)	= - 0.13 + 0.34*C1		=C21*D21
22	20	2x1.5 mm cable (roll)	= - 0.09 + 2*C1		=C22*D22
23	21	Lamp fittings (roll)	= - 0.02 + 0.2*C1		=C23*D23
24	22	Switches (unit)	= 0.09 + 0.13*C1		=C24*D24
25	23	Stop contacts (unit)	= - 0.16 + 0.12*C1		=C25*D25
26	24	Paint (kg)	= 2.09 + 0.14*C1		=C26*D26
27			TOTAL		=SUM(E3:E26)
28					

Figure-6. Display program for calculating material.

Making the correct program, in accordance with the stages that have been described, after completion will look like in the display Figure-6. Using this program, calculating the amount of material needed is very easy and fast. For example, to calculate the amount of material needed for a house construction project, with a building area of 70 m2 using this program, as shown in Figure-7.

If the unit price of material is known, enter the unit price of the material in column D, for example the price of foundation stone materials is known to be 150,000 / m3, cement 1,000 / kg, up to the 24th material, for

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example paint price of 30,000 / kg. Based on the data information above, using this program it is very easy to calculate it. The results of calculations using the program as shown in Figure-7.

	A	B	C	D	E
1		**Building area**	**70**	←	Enter variable X
2	**Number**	**Descriptions**	**Model**	**Unit price**	**Amount**
3	1	Foundation stone (m^3)	11.89	150,000	1,783,500
4	2	Cement (kg)	12665.43	1,000	12,665,430
5	3	Sand (m^3)	40.96	250,000	10,240,000
6	4	Gravel (m^3)	11.53	250,000	2,882,500
7	5	Brick (pcs)	17480.22	1,000	17,480,220
8	6	Ceramics (m^2)	75.35	70,000	5,274,500
9	7	8 mm concrete steel (kg)	4056.63	9,000	36,509,670
10	8	12 mm concrete steel (kg)	1727.57	9,000	15,548,130
11	9	C mild steel channel (rod)	69.52	70,000	4,866,400
12	10	Mild steel lath (rod)	104.44	35,000	3,655,400
13	11	Roof tiles (pcs)	1257.27	6,000	7,543,620
14	12	Roof ridge (pcs)	33.32	20,000	666,400
15	13	Planks (sheet)	69.26	25,000	1,731,500
16	14	Hollow steel (rod)	120.43	25,000	3,010,750
17	15	Gypsum (sheet)	120.43	65,000	7,827,950
18	16	PVC pipe 4" (rod)	18.96	225,000	4,266,000
19	17	PVC pipe 3" (rod)	31.37	195,000	6,117,150
20	18	PVC pipe ¾" (rod)	21.2	125,000	2,650,000
21	19	PVC pipe ½" (rod)	23.67	85,000	2,011,950
22	20	2x1.5 mm cable (roll)	139.91	450,000	62,959,500
23	21	Lamp fittings (roll)	13.98	45,000	629,100
24	22	Switches (unit)	9.19	25,000	229,750
25	23	Stop contacts (unit)	8.24	25,000	206,000
26	24	Paint (kg)	11.89	30,000	356,700
27		**TOTAL**			**211,112,120**
28					

Figure-7. Display program usage.

Material prices in Indonesia in regency and province regions there are differences in unit prices, in addition to different unit prices in each region, there is a change in prices every year, therefore the focus of this study is only to predict the amount of material needed in housing construction projects, while the material costs can enter it manually according to the applicable price.

CONCLUSIONS

This research has produced a solution, over the problem of the difficulty of predicting the amount of material needed in a residential construction project. Generating a solution to the problem of inaccuracy in providing the required amount of material, which often causes delays in the project and causes losses, for the contractor or whoever is carrying out the housing construction project. From now on calculating the amount of material needed for a residential construction project, can use models. These models have been compiled into an application program. Using the application program, calculating the amount of material needed, simply enter the planned building area information. By entering the building area data, then automatically the amount of material needed can be predicted. Using this program application, calculating the required materials becomes easy and fast, can save quite a lot of time. This program is quite accurate, only has an average error difference of under 5%. Furthermore, the delivery of material to the project needs to adjust the number of deliveries to the planned schedule.

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