

RESEARCH PAPER

Preliminary Cost Estimation Modeling for School Buildings in Sulaimani Governorate

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ABSTRACT:

Cost estimation for any construction projects at the early stage is a significant attempt, which has a main role in the success of the construction projects, because estimation at the early stage before design is very desired for decision maker to decide whether to start or not according to available budget. All parties involved in construction work as (owners, engineers, contractors and others) pay a great attention to this stage where limited information is available with no drawings or designs even no specifications. The objective of this research is to derive a model relating the cost of project as awarded with several independent variables (parameters) which are; site area, building area, duration(days), earthwork, area of doors and windows, number of floors, number of columns, distance from the city center(km), by utilizing linear regression techniques. The research methodology consists of data collection of 52 school building projects from public sectors which carried out between 2007 and 2014 in Sulaimani governorate. The models have been developed by applying Excel program and Minitab 19 software, then the models have been summarized and best one has been selected. Also, several statistical procedures have been conducted such as R^2 , R^2 - adjusted and two sample t-test were used to select more reliable equation. To find out the accuracy of each developed model, the author calculated mean absolute percentage error (MAPE). The range was between 25.3% and 46%. The R^2 was between 0.87 and 0.977 and also the p -value from two sample t- test was between 0.891 and 0.991.

KEY WORDS: Cost; Estimation; Model; Pre-Design; Regression.

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1. INTRODUCTION

Early stage cost estimation is a cost measuring which is used for prediction of the cost of a project before planning and design phase (Alumbugu et al.,2014). Early cost estimation is a systematic process which has a great impact on the new construction projects. Estimating is an essential part of the engineer's work; therefore, a great interest will be received over the years (Mahamid et al., 2010).

The conceptual cost estimation has a great effect on the future of the project success. This process depends on the background, which enters the taking out of different relationships between cost and its effect factors (Adel et al., 2016). Cost is one of the main principles for making decisions at the early stages of a building design process (Gunaydin et al., 2004). Any successful project is known by gathering three criteria, which are fitting cost with budget, implementing on time and quality as specified by the owner (Rezaian, 2011) (Shehatto, 2013). Wrong budget estimation or incorrect scheduling can simply switch and invert a predictable profit to loss (Cheng et al, 2010). In today's global competitive world, moving back profit limits and decreasing market stocks, cost control plays a major role for being competitive while maintaining high quality levels (Gunaydin et al., 2004). Therefore, effective

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estimating is one of the most important factors of a construction project attainment (Al-Shanti, 2003). The cost of a building is influencing expressively by decisions made at the design phase. While this effect decreases through all stages of the building project, which allows owners and planners to evaluate project option and control costs successfully. Due to the great role of cost estimate in early stage and incomplete information during the early phase of a project, construction managers generally use their knowledge, practice and standard estimate procedures to measure project costs. Therefore, such perception plays important part in helping project owners and planners in their early decisions. Researchers have worked hard to find out best way to develop cost estimate techniques that maximize the applied value of limited information in order to improve the exactness and dependability of cost estimation work (Cheng et al., 2010). Thus, many methods and techniques have been investigated either traditional or artificial intelligence methods to predict and estimate preliminary cost of the project at early stage.

2. Literature review

Cost estimating is a decisive part of construction projects, where cost is considered as one of the most important criteria in decision making at the early stages of building design process (Gunaydin et al., 2004). Numerous projects tolerate suffering and possible profit loss because of unsystematic cost and schedule following practices as well as erroneous data collection and estimates (Al Jawhar & Araji, 2016). The reliability of estimation is an important factor in the success of any construction project, since cost overruns are a main problem, especially with recent weight on firm budgets. Certainly, cost overruns can lead to end up of a project. In some cases, a possible overrun may result in cancellation of a project (Feng et al., 2010). One of the most important problems facing the construction management process is the occurrence of change orders, which became expected in every construction project and the magnitude of these variations differs from project to project. Considerably causing different effects to the project like changes in cost, time, quality, and completion schedule. One of the most significant causes of the change order come to poor cost estimation (Khalil Ismail & Saber,

2019). Many studies have been done about preliminary cost estimation for construction projects. (Lawther et al., 2001) Investigated in their study a statistical analysis techniques for evaluating historical data by regression analysis. The evaluation started at specifying the main parameters then find out the mathematical relationships between those parameters in the format of an algebraic equation. From 1970s till now continuously regression model is applying for determining cost. "The purpose of linear regression is to use the linear relationship between a dependent variable (e.g. estimated final cost) and independent variables (e.g. location, size) to predict or explain the behavior of the dependent variable. Multiple regression analysis is generally represented in the form: $Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \dots + \beta_nX_n$. Where Y is the total estimated cost; β_0 is a constant or line intercept; and X1, X2, etc. are the measures of variables that may help estimate y; and $\beta_1, \beta_2 \dots$ etc. are the coefficients estimated by regression analysis. The regression equation can then be used to predict the value of a dependent variable once the values of the independent variables are inserted". (Merrow and Yarossi (1990) cited by (Baccarini, 2005)) used y as the measured cost/real cost and x as main parameters.

(Shehatto, June 2013) Focused in developing a model for cost estimation of building projects in pre-design stage with a high degree of accuracy by Artificial Neural Networks. The percentage of accuracy of his modified model was more than (94 %). The sensitivity analysis of the study presented that the area of typical floor and number of floors are the most significant parameters in building cost.

(Lowe, 2006) used 286 sets of historical project data for developing a linear regression models for estimating the cost of building projects. The researcher worked on 41 independent parameters for developing a regression model. The study indicated that five of the independent parameters such as gross internal floor area, building function, duration, mechanical installations, and piling, had a great impact on the total cost.

(Kim et al., 2004) examined of three techniques for developing cost estimation models, the examinations are based on multiple regression analysis (MRA), neural networks (NNs), and case-based reasoning (CBR) of the data of 530

historical costs. the result of their study showed that the more accurate model for estimating new projects in future was (NN), then (CBR) was better than (MRA) for predicting new projects.

(Kim et al., 2013) focused on exploring the most dependable and exact cost estimation for school construction projects by comparing the accuracy result of three used techniques (regression analysis (RA), neural network (NN), and support vector machine techniques (SVM)) using historical cost data, for developing the three different models. The result of their study clearly showed that the most reliable models for estimating new projects was NN than the RA and SVM models. Subsequently, it is determined that to more accurate estimation, NN model is most appropriate techniques especially to school building projects.

(Barakchia et al., 2017) investigated different methods and their application for estimating total cost of transport projects. The study was depended on literature review and a quantitative data analysis was examined to find out the regularity of each method, as a result among 12 cost estimation methods according to accuracy; usability/application and acceptance, the parametric, artificial neural network and unit cost methods were the most used methods along the transport infrastructure.

3. Research Methodology

Regression analysis was used to develop a model for estimating the construction costs of school building in Sulaimani Governorate. By reviewing the literature, eight parameters were defined for developing a model such as, duration (days), site area (m²), building area (m²), number of floors, number of columns, earthwork (m³), area of doors and windows (m²) and distance from the city center (km). several statistical analyses were conducted then the models were developed and summarized. Before choosing the best model the accuracy of each model was checked.

3.1 Data Collection

The data gathered in administrative public sectors including construction firms, institutions and government branch ministries in Sulaimani Governorate. The collected data consists of 52 school building projects which implemented between 2007 and 2014. The main parameters involved the cost of the projects are eight

parameters; table.1 shows the summarized characteristic of data collected.

Table.1. Characteristic of data collection.

	Variables	Description	Min.	Max.	Average
Input	X1	Site area (m ²)	732	8400	4834
	X2	Building area (m ²)	182	5550	1516
	X3	No. of floor	1	2	
	X4	No. of columns	0	57	28.5
	X5	Duration (days)	115	529	255
	X6	Earthwork (m ³)	258	16350	3720
	X7	Area of Door & Window (m ²)	62	916	275
	X8	Distance (Km)	0	184	76
Output	Y	Total construction cost (ID)			

3.2 Model Development

MiniTab software version 19 and Excel program have been used for developing regression models, data and variables have been recognized, a sequence of mathematical models has been developed. The typical model is shown below:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_n X_n \dots \dots \dots (1)$$

Where;

Y.... is the dependent variable which refers to the Total Cost of the project

X₁ ...X_nare the independent variables, which refers to the site area (m²), Building area (m²)... etc.

β_i's..... are regression estimated parameters.

4. Result and Discussion

Linear regression techniques were used for developing a set mathematical model and the results for all tests prove the capability of the tests which are shown in the Table (2):

Table.2. Criteria Results.

N (Number of Projects)	52
R ²	0.92
Adjusted R ²	0.90

The following sections shows eight different regression models that developed to forecast the total cost of the school building projects as below:-

1. Cost-Duration Model(days)

The entire cost of the school building projects utilized as the dependent variable and actual duration in days utilized as the independent variable, $C= f(D)$. The regression model was developed and the result is shown in Table (3).

Table.3. Total cost- Actual duration model.

Model	Independent variables	coefficients	ρ-value	AdjustedR ² (R ² used only for one Variable)
1	(Constant)	-490345504.71	0.00	0.76
	Actual duration (days)	4618929.18	0.00	

The model relating cost of project with duration of execution is as follow:

$$\text{Total Cost} = (4618929.18 * \text{Actual Duration}) - 49034550 \dots \dots \dots (2)$$

2. Cost estimating model depends on Actual Duration (days) and Site Area (m²)

The entire cost of the school building projects utilized as the dependent variable and actual duration in days with site area in square meter utilized as the independent variables, $C= f(D, SA)$. The result of developed regression model is shown in Table (4).

Table.4. Total Cost- Actual Duration and Site Area

Model	Independent variables	coefficients	ρ-value	R ² - Adjusted
2	(Constant)	-644513031.45	0.000	0.82
	Actual duration (days)	3464587.69	0.000	
	Site area (m ²)	91378.398	0.000	

By inserting second parameter relating total cost of project which is site area with duration the model will be in the form shown below: -

$$\text{Total Cost} = (3464587.69 * D) + (91378.398 * SA) - 644513031.45 \dots \dots \dots (3)$$

3. Cost estimating model depends on Actual Duration (days), Site Area (m²) and Building Area (m²)

The whole cost of the school building projects utilized as the dependent variable and actual duration in days, site area in square meter and

building area in square meter utilized as the independent variables, $C= f(D, SA, BA)$. The result of developed regression model is shown in Table (5).

Table.5. Total Cost- Actual Duration, site Area and Building Area

Model	Independent variables	coefficients	ρ-value	R ² - Adjusted
3	(Constant)	-373439225	0.0042	0.86
	Actual duration (days)	2447413.913	0.000	
	Site area (m ²)	38723.23017	0.156	
	Building area (m ²)	160823.6813	0.001	

By inserting third parameter relating total cost of projects which is Building area with duration and site area the model will be in the form shown below: -

$$\text{Total Cost} = (2447413.913 * D) + (38723.23017 * SA) + (160823.6813 * BA) - 373439225 \dots \dots \dots (4)$$

4. Cost estimating model depends on Actual Duration (days), Site Area (m²), Building Area (m²) and Number of floors.

In the fourth model, the whole cost of the school building projects utilized as the dependent variable and actual duration in days, site area in square meter, building area in square meter and numbers of floors utilized as the independent variables, $C= f(D, SA, BA, NF)$. The result of developed regression model is shown in Table (6).

Table.6. Total Cost-Actual duration, Site area, Building Area and Numbers of floors.

Model	Independent variables	coefficients	ρ-value	R ² - Adjusted
4	(Constant)	-30579757	0.063	0.86
		1.2		
	Actual duration (days)	2593949.35	0.000	
	Site area (m ²)	39471.29	0.152	
	Building area (m ²)	185945.95	0.004	
	Nos. of floors	-10833390	0.509	
	2.1			

By inserting fourth parameter relating total cost of project which is number of floors with duration,

site area and building area the model will be in the form shown below: -

$$\text{Total Cost} = (2593949.35 * D) + (39471.29 * SA) + (185945.95 * BA) - (108333902.1 * FN) - 305797571.2 \dots (5)$$

5. Cost estimating model depends on Actual Duration (days), Site Area (m²), Building Area (m²), Numbers of floors and No. of Columns.

The whole cost of the school building projects used in this relationship as the dependent variable and actual duration in days, site area in square meter, building area in square meter, numbers of floors and No. of Columns utilized as the independent variables, C= f (D, SA, BA, FN, NC). The regression model was developed and the result is shown in Table (7).

Table.7. Total Cost- Actual duration, Site area, Building area, No. of floors and No. of columns.

Model	Independent variables	coefficients	ρ-value	R ² - Adjusted
	(Constant)	-274657045.1	0.110	
	Actual duration (days)	2689583.76	0.000	
5	Site area (m ²)	36748.3799	0.189	0.86
	Building area (m ²)	204120.1588	0.004	
	Nos. of floors	-149629956.2	0.398	
	No. of columns	-1997551.064	0.505	

By inserting fifth parameter relating total cost of project which is No. of columns with duration, site area, building area, No. of floor the model will be in the form shown below:

$$\text{Total Cost} = (2689583.76 * D) + (36748.3799 * SA) + (204120.1588 * BA) - (149629956.2 * FN) - (1997551.064 * NC) - 274657045.1 \dots (6)$$

6. Cost estimating model depends on Actual Duration (days), Site Area (m²), Building Area (m²), Numbers of floors, No. of Columns and Earthwork (m³).

The cost of the school building projects used in this relationship as the dependent variable and actual duration in days, site area in square meter, building area in square meter, numbers of floors, No. of Columns and Earthwork used as the independent variables, C= f(D, SA, BA, FN, NC, E).The result of developed regression model is shown in Table (8).

Table.8. Total Cost- Actual duration, site area, Building area, No. of floors, No. of Columns and Earthwork.

Model	Independent variables	coefficients	ρ-	R ² -
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	variables	value	Adjusted	
	(Constant)	-228378117.7	0.194	
	Actual duration (days)	2544598.69	0.000	
6	Site area (m ²)	32459.37	0.249	0.86
	Building area (m ²)	209383.80	0.003	
	Nos. of floors	-185607666.2	0.303	
	No. of columns	-2181587.198	0.467	

By inserting sixth parameter relating total cost of project which is earthwork with duration, site area, building area, No. of floors and No of columns the model will be in the form shown below:

$$\text{Total Cost} = (2544598.69 * D) + (32459.37 * SA) + (209383.80 * BA) - (185607666.2 * FN) - (2181587.198 * NC) + (13691.73 * E) - 228378117.7 \dots (7)$$

7. Cost estimating model depends on Actual Duration (days), Site Area (m²), Building Area (m²), Numbers of floors, No. of Columns, Earthwork (m³) and Area of Doors and Windows (m²).

The cost of the school building projects used in this relationship as the dependent variable and actual duration in days, site area in square meter, building area in square meter, numbers of floors, No. of Columns, Earthwork and area of doors and windows used as the independent variables, C= f(D, SA, BA, NF, E, NC, ADW).The result of developed regression model is shown in Table (9).

Table.9. Total Cost- Actual duration, Site area, Building area, No. of floors, No. of columns, earthwork, Area of doors and windows.

Model	Independent variables	coefficients	ρ-value	R ² - Adjusted
	(Constant)	-60476606.87	0.684	
	Actual duration (days)	1422584.841	0.017	
	Site area (m ²)	45335.58077	0.057	
7	Building area (m ²)	99809.16566	0.112	0.90
	Nos. of floors	-340358596.7	0.031	
	No. of columns	-3951600.279	0.120	
	Earthwork	15400.24977	0.150	

Area of doors and windows	1613924.91	0.000
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By inserting seventh parameter relating total cost of project which is area of doors and windows with duration, site area, building area, no. of floors, no. of columns and earthwork the model will be in the form shown below: -

$$\text{Total Cost} = (1422584.841 * D) + (45335.58077 * SA) + (99809.16566 * BA) - (340358596.7 * NF) - (3951600.279 * CN) + (15400.24977 * E) + (1613924.91 * ADW) - 60476606.87 \dots\dots\dots (8).$$

8. Cost estimating model depends on Actual Duration (days), Site Area (m²), Building Area (m²), Numbers of floors, No. of Columns, Earthwork (m³), Area of doors and windows and Distance from the city center (km).

The cost of the school building projects in total used in this relationship as the dependent variable and actual duration in days, site area in square meter, building area in square meter, numbers of floors, No. of Columns, Earthwork, area of doors and windows and distance from the city center used to be independent variables, C= f(D, SA, BA, NF, CN, E, ADW, Di). The result of regression model is shown in table (10).

Table.10. Total Cost- Actual duration, Site area, Building area, No. of floors, No. of columns, earthwork, area of D&W, Distance from the city center.

Model	Independent variables	coefficients	ρ-value	R ² - Adjusted
	(Constant)	-12794469.66	0.933	
	Actual duration (days)	1437130.47	0.016	
	Site area (m ²)	40168.06	0.095	
	Building area (m ²)	85235.72	0.179	
8	Nos. of floors	-284795798.8	0.081	0.90
	No. of columns	-3270639.33	0.207	
	Earthwork	14961.24	0.161	
	Area of doors and windows	1514231.65	0.000	
	Distance from the city center (km)	-716289.53	0.267	

By inserting eightieth parameter relating total cost of project which is distance from city center with duration, site area, building area, number of floors, number of columns, earthwork and area of doors and windows the model will be in the form shown below: -

$$\text{Total Cost} = (1437130.47 * D) + (40168.06 * SA) + (85235.72 * BA) - (284795798.8 * NF) - (3270639.33 * CN) + (14961.24 * E) + (1514231.65 * ADW) - (716289.53 * Di) - 12794469.66 \dots\dots\dots (9)$$

9. Mean absolute percentage error (MAPE)

Excel program has been used to find the percentage of error of each model by calculating mean absolute percentage error (MAPE). Below is the rule for calculating (MAPE):

$$MAPE = \frac{\sum_{i=1}^n \left| \frac{Ce - Ca}{Ca} \right|}{N} * 100 \quad (10)$$

Where

MAPE= mean absolute percentage error,

Ce= estimated cost,

Ca= actual cost,

N= no. of tested data

Ce-Ca= error.

For checking the reliability of equations, 13 of collected data was used to calculate MAPE and R² between actual and estimated cost as shown in table.11. The dependability of each equation was conducted by using 13 data from historical collected data to compute MAPE and R² between actual and estimated. To select best model among eight obtained models, minimum MAPE% and maximum R² were required. Model #8 had minimum MAPE% which was 25.3%, since maximum R² was taken by model #7 which was 0.977. therefore, it was confusing indication to choose best model by MAPE% and R² only. Further evaluation has been done to measure the presentation of the eight equations. Nonparametric two sample test was made, in first step the normality of the result from the equations were studied. Conditional on normality of the actual and estimated cost data, then the statistical tests were used to check the dependability of equations. The statistical results (actual and estimated cost) were normally distributed. F-test to compare the variance of both actual and estimated cost data has been performed to check equality of variances and two-sample t-test was used to compute p-value. Table.12 shows the p-value from two sample t-test with equal variance. Therefore, the best model is model 8, it can be applied to estimate cost for school building projects. If comparing this result to the study of (kim, et al, 2013) which focused on the cost estimation modeling for school building. The author of that study used mean absolute error

rates (MAERs) for measuring performance of each models and got 10% if compared to our study which was 25.3%, the difference happened depends on the following points:

1. Different place of working.
2. The range of years, which the author took only three years from 2004 to 2007, while we used wide range from 2007 to 2014.
3. Number of data, the author used 197 data set for developing the regression model while the current data just 52 data.
4. Different input parameters.

Table.11. Results of evaluation criteria for equations of Actual cost compared to Estimated cost data.

NO.	Equation Number	Evaluation Criteria	
		MAPE %	R ²
1	Eq.2	33.85	0.871
2	Eq.3	46.03	0.908
3	Eq.4	29.83	0.921
4	Eq.5	31.44	0.926
5	Eq.6	29.6	0.935
6	Eq.7	29.39	0.939
7	Eq.8	27.33	0.977
8	Eq.9	25.3	0.969

Table.12. Results of two sample t-test with equal variance.

Equation No.	Normality test		P-value from two sample t-test
	Actual Cost	Estimated Cost	
Eq.2	>0.005	> 0.005	0.942
Eq.3	>	> 0.005	0.949
Eq.4	0.005	> 0.005	0.958
Eq.5	>	> 0.005	0.973
Eq.6	0.005	> 0.005	0.931
Eq.7	>	> 0.005	0.891
Eq.8	0.005	> 0.005	0.965
Eq.9	>	> 0.005	0.991

5. Conclusion and recommendation

In this study, eight regression models were developed to estimate total cost of school building project. The models were checked by a part of historical collected data. The following conclusions can be shown:

- According to previous studies that have studied in the same arena displays that the estimate accuracy in the early stage of construction project process is between $\pm 25\%$ and $\pm 50\%$.

- The accuracy of the models MAPE are between 25.3%-46%.
- The value of coefficients (R²) and (adjusted- R²) for the formed models are between 0.871 and 0.977 which tell us that the relation between dependent and independent parameters are strong enough to be relied on.
- Depend on the study magnitude of R² of the models increase with increasing number of variables.
- It is recommended to choose model 9 which its MAPE= 25.3% and R²=0.969 and depends on more parameters compared to other models.

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