

Conceptual Cost Estimate of Buildings Using Regression Analysis In Egypt

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Abstract:

Background: The project cost is an inevitable step in the conceptual phase of the project, as it can influence or change the project scope. The cost estimate at this stage faces many difficulties due to the limited data at this stage. This research aims to develop a Regression models for estimating the cost of construction projects in the conceptual stage. The proposed model will serve as a tool that could be used by all parties involved in the project and will facilitate the cost estimation process at the conceptual phases of projects through more effective utilization of the limited available information.

Materials and Methods: The regression analysis techniques are the mathematical methods which used widely in several fields. Seven factors affecting cost estimation were identified; slab type, typical floor area, number of floors, number of elevators, type of internal finishing, type of external finishing, and type of electro-mechanical work. The proposed models was developed using 131 real projects.

Results: The absolute percentage of errors for the S-curve regression was 25.24%, which indicates that it is the best proposed model. The S-curve regression has high accuracy in estimating the total cost of construction projects at the conceptual stage. The highest MAPE directed in this study was 66.2% for the logistic method, while the MAPE of the power analysis was 61.55%, and the inverse model also has unacceptable MAPE. Moreover, Logarithmic analysis has low accuracy because its MAPE exceed 50%. The MAPE of the Quadratic technique was 41.48%, whereas the MAPE of the Growth technique was 37.51%. The cubic analysis technique has acceptable accuracy performance and it's MAPE was 31.26 %.

Key Word: construction cost; residential building; regression analysis; Fuzzy logic.

Date of Submission: 05-09-2020

Date of Acceptance: 20-09-2020

I. Introduction

The cost is considered as one of the three essential objectives that had to achieve by construction project manager. In fact, the primary cost evaluation is undoubtedly the main pillar for a successful construction project¹. It is also deemed to be a critical phase in any construction project because it enables engineers and Clients to assess the feasibility of the project accurately². Poor methodology or inaccurate determination of budget can adversely impact the process and turn an expected profit into loss. Cost estimating in this early phase faces many difficulties due to the limited data throughout the conceptual stage of a project³. All construction project parties usually rely on traditional methods, such as their own knowledge and expertise, as well as standard estimators to estimate construction project costs. Thus, instinct and expertise play an essential role in the decision-making process⁴. These mathematical techniques significantly increase the accuracy of the project's cost estimating and maximize the benefit of limited available information due to the grave need for tools to assist projects owners in the decision-making process. Therefore, several mathematical approaches, have been recently analysed and examined to assess their reliability in projects cost estimation at the early conceptual phase⁵.

II. Material And Methods

Cost is a very important standard and should be taken into account during the early stage of any construction project, so cost estimation is crucial in construction related projects⁶. The accuracy of the estimation is very important to achieve the objective of any Construction project, where cost overruns can lead to serious obstacles, for instance project termination, especially on the current focus on limited budget. Possible unexpected changes may in some suitcases transform a project into a design-to-cost task⁷.

Early cost estimate has a great effect on the decision of the owner and project manager and also has impact on the outcomes of the final project. As a result, the project decision-makers began to do more effort on the Preliminary plan phase, where the good estimation for the project in this Preliminary stage is an essential

component leading to help the project to fulfil its goals. Cost estimate is regarded as a unit of the information essential components for taking decisions at the Preliminary stage ⁸.

Commonly, the sum of the available information during the estimation process is what the accuracy of any estimates rely on⁹. The accuracy range increases during a project as the quantity and quality of information increases. Meaning accuracy estimation is the availability of the data. Great evaluating exercise and having encountered work force can influence the exactness of an evaluation. Particularly, conceptual estimates as they have a very low scope definition and mostly weakly expressed¹⁰. The CII's study underlines the key factors impacting estimate accuracy in the traditional methods¹¹:

1. The condition and the number of data available for making an assessment.
2. The period required for the planning of an assessment.
3. The proficiency and efficiency of the estimating team.
4. The tools and techniques used in the preparation for an estimate.

Based on the level of project's definition, the (AACE Recommended Practice and standard) specified three types of estimation¹²:

- 1- Accuracy range of Conceptual estimate is between (-30% to +50%)
- 2- Accuracy range of budget estimate is between (-15% to +30%)
- 3- Accuracy range of definitive estimate is between (-5% to +15%)

There are previous researches study the project cost estimation, factors influencing cost assessing, and the PC models in cost assessing. Al-Shanti (2003) researched the project cost estimation in a project. He looked up the usage of cost estimate in computer applications. He found that majority of the contracting companies are still using manual methods for cost estimation. The fundamental hindrances in utilizing PC in development estimation are deficiency of easy to use evaluating programming bundles and absence of accessible qualified work force in utilizing PC based assessing frameworks¹³.

While Memon et al. (2010) was considering the elements that influences development cost at MARA, or, in other words the administration organizations in Malaysia. They exhibited the consequences of a poll review that was led among the faculty of Venture Administration Expert. They presumed that there are most serious factors; for example, income and budgetary challenges looked by temporary workers, contractual worker's poor site administration and supervision, insufficient contractual worker encounter, lack of site laborers, inaccurate arranging and booking by contract-based workers, while the minimum influencing factors are changes in extent of task and successive outline changes¹⁴.

Then again, Cheng et al. (2009) found a theoretical cost gauge demonstrate by the Transformative Fuzzy Neural Surmising, they displayed Developmental web-based early stage Cost Estimators, which can be sent to evaluate applied development cost amid the task's beginning periods¹⁵.

After that, Arabzadeh (2017) established three cost factors affecting the construction of spherical storage tank. These cost factors are tank diameter, thickness, and length of the weld. He found that the ANN technique has a significant ability for estimating of spherical tank project costs in the conceptual phases. The correlation between real data and estimated values is over 90%, while the mean square error is achieved around 0.4¹⁶.

Also, Matel (2019) examined ML-based cost estimation method for engineering services utilizing a neural network model. He researched the management of software applications to deal with all the risk and obligations related to the engineering services projects. This paper presented that ANN can be used to gain a reliable cost estimate at the conceptual phase. He discovered that formalized techniques are used by most contractors for estimating contingencies when preparing tenders. Matel depend on 7 input variables in building his model which are: (1) intensity, (2) number of project team members, (3) project duration, (4) collaborating disciplines, (5) contract type, (6) project phases, (7) scale of work¹⁷.

Elmousalami used twenty machine learning models to estimate the cost of Field canal improvement projects (FCIPs). Elmousalami conducted unreliable results of fuzzy logic because the MAPE of his Fuzzy model was 26.3%. The factors used in his study were area served, pipeline length, the number of valves, and year of construction. The data were collected from 144 real projects between 2010 and 2015. Elmousalami divided these data into a 111 project that used for developing the models and 33 projects to test the models Elmousalami¹⁸. Factors affecting the cost estimate and their references were shown in table no (1).

Table no 1: Factors affecting the cost estimate and their references

| Factor/ reference | [20] | [21] | [22] | [19] | [23] | [24] | [25] | [26] |
|--------------------|------|------|------|------|------|------|------|------|
| Floor Area | √ | √ | √ | √ | √ | √ | √ | √ |
| Number of stories | √ | √ | | √ | √ | √ | √ | √ |
| Slab type | √ | | | √ | | √ | | |
| Internal Finishing | √ | | | | √ | √ | | |

| | | | | | | | | |
|-------------------------------------|--|---|--|---|---|---|---|---|
| Number of elevators | | √ | | √ | | √ | √ | √ |
| External finishing | | | | √ | √ | √ | √ | √ |
| Type of electrical-mechanical works | | | | √ | | √ | | |

Traditional techniques for cost estimation in building projects are the most used. Traditional techniques rely on computerized systems or Excel sheets which are time-saving and more accurate²⁷.

The assigned methodology to complete this research used historic information, that analysis, to create the data base for the computerized system that estimate total construction cost for new projects depending on the key factors gathered from the owner in predesign stage. Also, this section withdraws the research strategy, the research limitation; research Sample Size; the used procedures of collecting data; and analysing data.

First of all, the factors that affect the cost estimate were defined. The defining process depends on reviewing the literature from related previous studies, which view the conceptual cost estimation for construction. Then questionnaire survey was conducted to discover the essential factors that affect the construction projects cost estimation. After that the experts sent back their opinion on the First list. From their reviews, we established a second list of factors and resent to the experts. In the third round, the factors list was approved from all experts. This final list consist of seven important factors which were slab type, floor area, stories number, elevators number, internal finishing type, external finishing type, electro-mechanic type. The classifications of each factor were shown in Table no 2.

Table no 2: The classifications of the factors affecting the cost estimate in residential building

| Factor | Category |
|------------------------|--------------|
| slabType | Solid |
| | Flat |
| | Hollow block |
| floorArea | (100- 400) |
| | (400- 800) |
| | (800- 1200) |
| floorsNumber | (1-3) |
| | (4-6) |
| | (7-9) |
| | (10-12) |
| elevators Number | (1) |
| | (2) |
| | (3) |
| Internal Finishing | Basic |
| | Intermediate |
| | Luxury |
| External Finishing | Basic |
| | Intermediate |
| | Luxury |
| electro-mechanic works | Basic |
| | Intermediate |
| | Luxury |

There are two research strategies which are quantitative and qualitative research. Quantitative research relies mainly on numerical data, analyses this data, and explains the relations of the data²⁸. In this study, the strategy of quantitative was used. The survey also gathered real information about the effecting factors and actual total cost of construction projects. The questionnaire study collected 131 project cases were collected and divided them to two collections, 113 projects for creating the regression models and the other 18 projects for testing the models. The population in this study was considered all the residential projects that occurred in Egypt between 2013 and 2017 which can be considered as a very large and unspecified number, hence, the authors considered that a population number is an infinite number. The number of sample size is computed using equation (1).

$$SS = \frac{z^2 * (P) * (1-P)}{c^2} \quad (1)$$

Where SS represents the sample size, Z represents the normalized value, P represents the percentage of picking a specific choice, C represents the confidence interval expressed as a decimal. In this research, the sample size, which was 131, the normalized value was 1.96 which concerns, 95 % level of confidence, all the identified factors were classified into three or four categories hence the value of picking a choice was selected to be 0.33 for maximized the sample size, hence, the confidence interval was 0.08.

The collected data were considered as a database to be used as inputs in the regression models. The regressionsystems wererealized using the Excelsheet to guess the effecting of the factors on the project cost. The ease of use of this program to build and operate the models is the main reason for choosing it.

The creation of the regression Systems relied on 113 real projects to conduct the coefficients for each type of regression analysis technique. First of all, inserting the projects data base and determining the independent variables and the dependent variable. The cost which is the outcome of this study, considers as dependent variable in SPSS program. Then the mathematical function of each regression method was defined. After that, it is needed to realize the coefficients for each regression mathematical function. The proposed models were tested using data obtained from 18 real projects and comparing model results with the modified actual cost of these projects. These mathematical methods consider as the easiest procedures to evaluation the output depending on many different variables. Nine regression techniques were conducted to create a cost estimate models.

Reliability was dignified by numerousmethods such as alternate forms method, split-half method, and test-retest. ALTERNATE FORMS METHOD considers as creating some equipollent tests then correlating the results of each test. SPLIT HALF METHOD is implementing through dividing the items of the test into two equivalent matching halves then correlating the results of each half. TEST_RETEST is administering by applying the same test in several different time²⁹. Validity can be easily checked by asking experts or pilot respondents whether the testing items, that were developed, are expected to do the purpose. The testing procedures of the validity require at least three experts who have full understanding of the study objectives. The three experts have to approve that the designed questionnaire is valid enough to conduct its objectives ³⁰.

III. Result

In this section, different types of regression analysis method were been present. The regression analysis methods are widely used. Nevertheless these techniques have manyweaknesses such as it is not giving a clear approach to define the most appropriate model based on the available historical information and have low accuracy. These mathematical methods consider as the easiest procedures to evaluation the output depending on many different variables³¹. First of all, determine the model input and output. The system inputs contain seven factors which are: slab type, floor area, number of stories, elevators number, internal finishing type, external finishing type, and type of electro-mechanic works. The system output is the total construction building cost. The central purpose of this system is to get the output, which is expectation of the total project cost depend on the inputs factors. Eight regression techniques were conducted to create a cost estimate models. SPSS Statistics Data Document is the program which used in this research to conduct the coefficients for each type of regression analysis technique.

The comparison between the results of the regression models and the real construction cost to determine the degree of veracity for the model. The absolute percentage error of any project can be determined using equation (2). The absolute percentage error extracted from the regression models for the 18 cases in the testing phase. The mean absolute percentage error of the model was conducted can be calculated using equation (3). On the other hand, the accuracy of the model outcome can be stated in by accuracy performance according to equation (4) ³².

$$APE = \left(\frac{AC-EC}{AC} \right) * 100 \quad (2)$$

$$MAPE = \frac{\sum_{i=1}^N \left(\frac{AC-EC}{AC} \right)}{N} * 100 \quad (3)$$

$$AP = (100 - MAPE)\% \quad (4)$$

Where APE represents the absolute percentage error, AC represents the modified actual cost, EC represents the expected cost, MAPE represents the mean absolute percentage error, and AP represents the accuracy percentage.

Logistic regression analysis: is mathematical traditional method. The logistic analysis conducted in excels spreadsheet.

$$y = b * m 1^{x1} * m 2^{x2} * ... * m n^{xn} \quad (5)$$

This nonlinear method mainly depend on the constant coefficient which calculated from excel program. The function used in excel to get this coefficient is LOGEST (known_y's, [known_x's], [const], [stats]).

Logarithmic regression analysis: is non-linear traditional method. The easy accompanied of the logarithmic regression analysis is considering the advantage of this technique.

$$y = b * m 1^{x1} * m 2^{x2} * ... * m n^{xn} (6)$$

Inverse regression analysis: is mathematical traditional method. The purpose of using the Inverse analysis is to determine which method is better for estimating the cost of construction projects. The Inverse formula constants represent the weight of each factor that affecting the output. The relation between inputs and output is nonlinear as shown below.

$$y = b0 + \left(\frac{b1}{t1}\right) + \left(\frac{b2}{t2}\right) + \dots + \left(\frac{bn}{tn}\right) (7)$$

Quadratic regression analysis:is a functional relation between several input variables and the output. In the sector, the quadratic analysis constants conducted from SPSS Statistics Output Document. The quadratic function constants represent the weight of each factor that affecting the output.

$$y = b0 + (b1 * t1) + (b11 * t1^2) + \dots + (bn * tn) + (bnn * tn^2)(8)$$

Power regression analysis:is mathematical function used to determine output depend on power several input variables by constants. The advantage of power regression analysis is simply conducted as the other type of regression analysis methods, because it is very straightforward equation.

$$y = b0 * (t1^{b1}) * (t2^{b2}) * ... * (tn^{bn}) (9)$$

The constant coefficients which used in section were calculated from SPSS Statistics Output Document depending on the real project data base.

Cubic regression analysis: is a third degree functional relation between several input variables and the output. As the other type of regression analysis methods, the advantage of cubic regression analysis is simply conducted. In the case of cubic analysis, the relation between inputs and output is nonlinear as shown below.

$$y = b0 + (b1 * t1) + (b11 * t1^2) + (b111 * t1^3) + \dots + (bn * tn) + (bnn * tn^2) + (bnnn * tn^3)(10)$$

The constant coefficients which used in section were calculated from SPSS Statistics Output Document depending on the real project data base.

Growth regression analysis:is also mathematical traditional method. The growth analysis constants conducted from SPSS Statistics Output Document. The growth function constants represent the weight of each factor that affecting the output.As the other type of regression analysis methods, the advantages of growth regression analysis are 1- simply conducted, 2- Estimating of future responses, 3- estimating of responses exterior the statistics series. In the case of growth analysis, the relation between inputs and output is nonlinear as shown below.

$$y = e^{b0+(b1*t1)+\dots+(bn*tn)} (11)$$

The constant coefficients which used in section were calculated from SPSS Statistics Output Document depending on the real project data base.

The S-curve regression analysis: is a functional relation between several input variables and the output. The s-curve analysis constants conducted from SPSS Statistics Output Document. The s-curve function constants represent the weight of each factor that affecting the output. The s-curve regression analysis has many advantages such as 1-it is simply conducted, 2-In all cases of input levels, the s-curve analysis has good control of a process, and 3- offering a respectable explanation of the variables behavior in the process. In the case of s-curve analysis, the relation between inputs and output is nonlinear as shown below.

$$y = e^{b0+(b1/t1)+\dots+(bn/tn)} (12)$$

The results of the regression analysis showed that the most suitable regression method for the project cost estimating was the S-curve technique. The cubic and growth analysis methods performed respectable results. The other regression analysis techniques; Quadratic, Logarithmic, Inverse, power, and Logistic regressions have in appropriate results. The mean absolute errors for each regression technique were illustrated in table 3.

Table 3: the MAPE for the regression models

| NO. | Analysis Technique | MAPE |
|-----|--------------------|-------|
| 1 | S-curve | 25.24 |
| 2 | Cubic | 31.26 |
| 3 | Growth | 37.51 |
| 4 | Quadratic | 41.48 |
| 5 | Logarithmic | 50.85 |
| 6 | Inverse | 60.75 |
| 7 | Power | 61.55 |
| 8 | Logistic | 66.2 |

IV. Discussion

At the study of Cheng et al. (2009) found a theoretical cost gauge demonstrate by the Transformative Fuzzy Neural Surmising, they displayed Developmental web-based early stage Cost Estimators, which can be sent to evaluate applied development cost amid the task's beginning periods. They rely on two main effecting factor groups which are of 13 structural skeleton factors and the 18 finishes group factors [15]. Although the MAPE was 10.4%, This study depend on large number of factors and most of these factors can be considered as the conceptual stage.

Arabzadeh (2017) create ANN model to estimate the cost of spherical tank project. Herecognized only three effecting factors which are tank diameter, thickness, and length of the weld. The correlation is over 90%, and the mean square error is 0.4 [16]. He developed a good ANN model, but this model serve only the spherical storage tank projects.

Matel (2019) examined ML-based cost estimation method for engineering services utilizing a neural network model. He researched the management of software applications to deal with all the risk and obligations related to the engineering services projects. This paper presented that ANN can be used to gain a reliable cost estimate at the conceptual phase. He discovered that formalized techniques are used by most contractors for estimating contingencies when preparing tenders. Matel depend on 7 input variables in building his model which are: (1) intensity, (2) number of project team members, (3) project duration, (4) collaborating disciplines, (5) contract type, (6) project phases, (7) scale of work [17].

The regression models created in this study contains seven inputs. These effecting factors were slab type, floor area, stories number, elevators number, internal finishing type, external finishing type, and electro-mechanic type. This study regression model was based on 113 real projects. Then the model was examined by other 18 project.

The regression analysis techniques are the mathematical methods which used widely in several fields. The regression analysis techniques use mathematical equations. several regression methods were conducted in this study as shown in table 3, the regression analysis techniques were ranged based on the MAPE. The highest MAPE directed in this study was 66.2% for the logistic method, while the MAPE of the power analysis was 61.55%, and the inverse model also has unacceptable MAPE. Moreover, Logarithmic analysis has low accuracy because its MAPE exceed 50%. The MAPE of the Quadratic technique was 41.48%, whereas the MAPE of the Growth technique was 37.51%. The cubic analysis technique has acceptable accuracy performance and its MAPE was 31.26%. Finally, the best regression analysis technique in this case study was the S-curve technique. The MAPE of the S-curve regression was 25.24%.

V. Conclusion

The conceptual estimating of the project cost is very important, because the incorrect cost estimation or cost overruns may lead to project termination. According to the previous studies and this research surveying questionnaire, it is easily observed the majority of contractors and consultants still using the traditional estimating methods. It is observed that the seven factors divided to two critical groups. The first group consists of the skeleton factors containing the type of slab, the area of a typical floor, and the number of floors in the building while the second group concerns the stakeholder requirements containing the type of external finishing, the type of internal finishing, the number of elevators, and the type of electro-mechanical works.

This study regression models was based on 113 real projects. Then the model was examined by other 18 project. The regression models evaluating need a comparison between the results of the regression models and the real construction project cost. This comparison determines the degree of veracity for the model. The comparison in this thesis was conducted between the evaluated cost which determined from regression models and the actual cost which collected from real project. The regression analysis techniques are the mathematical methods which used widely in several fields. The regression analysis techniques use mathematical equations. The S-curve analysis method has the lowest MAPE in regression analysis methods.

The most significant recommendations which concluded from analysing the research model results, is summarized in the following sentences. All construction project parties, specially the consultants, need to histories the whole cost data for all project items and create a historic database from all completed projects. This distinctive data base will be, in the further, the central source for any cost data of any future construction project. This thesis study the cost estimate for reinforcement concrete building, so that it is needed to produce the cost estimate for steel structure building in the future studies.

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I. Badra, et. al. “Conceptual Cost Estimate of Buildings Using Regression Analysis In Egypt.”
IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), 17(5), 2020, pp. 29-35.