Stochastic Preliminary Budget Estimating Template for Construction Firms

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Abstract

In the construction industry, cost is proved to be one of the most important boundaries for many projects, and it is what defines their future. However, although proper estimation is crucial, it requires significant time and resources in order to be accurate. A quick preliminary estimation can be useful, mostly during the initial stages, for a company to decide whether it should go after a project, but in most cases it is based on human experience and rough assumptions. This paper presents an easy method of preliminary budget estimation which can be developed for, almost, any type of construction project, using MS Excel and @RISK. Using as the only input the area of the project, and selecting the pre-defined values expressing the intensity of the main Trades involved, we can estimate the project cost while achieving more than 80% accuracy. The main advantages of the presented template are its simplicity, flexibility, low cost and the relevant accuracy it achieves by using market prices. The paper presents step by step the development process of the template, analyzes its philosophy and discusses the main points through a real life case study from the US market.

Keywords
Stochastic Budgeting, Estimating Template, Preliminary Budget, Construction Estimating

1. Introduction

"Estimating construction cost is one of the essential tasks in the budget development phase of any project life cycle" (Abdou et.al, 2004). However, this is proved to be a quite difficult task when carried out under conditions of uncertainty. Especially, when it comes to General Contracting where the Contractor usually carries the whole risk of the project, accurate estimating is crucial. What is more, early budgeting is always required in order to provide the sponsor a range of costs for the development of the project (Tas and Yaman, 2005).

This is the main reason why many studies have been made in an effort to develop more accurate preliminary estimating methods for construction (Cheng *et al.*, 2009; Chou and O'Connor, 2007; Chou *et al.*, 2005). The disadvantage of these studies, however, is that in most of the cases they are highly sophisticated, thus preventing the user from understanding the process of the estimation and consequently making him/her reluctant to apply the method or tool in the everyday practice. This is maybe the reason why professional cost/budget estimation templates remain simplistic in nature and architecture to allow

easy application and understanding from the users' point of view (BuildingAdvisor.com, 2015; UDA Excel Templates, 2015; Total Takeoffs, 2015; etc.).

This paper presents a new Preliminary Budget Estimating Template (PBET) that, primarily, aims to aid in decision making tasks by providing a reliable early budget within a short period of time. To achieve that it goes one step beyond the similar templates that are, currently, met in the industry by incorporating, through the combination of the software tools MS Excel and @RISK, the theory behind statistics and stochastic methods, all expressed in a simple and user-friendly deterministic format. In this way, the proposed PBET achieves to *"capture and represent the reality being modeled as closely as is practical, yet including the essential features of the reality whilst being reasonably cheap to construct and operate and easy to use"* (Fellows and Liu, 1997).

The data, values, and assumptions presented in this paper are based on the data of 55 projects, which were estimated and constructed between the years 2012 – 2014 in the Metropolitan area of New York City.

2. Data Collection

2.1 Project Selection

A PBET that incorporates stochastic estimations requires appropriate data, in order to create a robust database to support these estimations. These data are obviously drawn from past projects, however this may be a very challenging task given the number of parameters that need to be considered. These parameters are:

- The type of the projects that could be used as a source of data for the development of a PBET. According to Koo, et al. (2010) it is imperative to have accurate and updated data and consider several implications in order to have accurate results. PBETs could not be seen as one-size fits all documents mainly, because different types of projects present significant variations, particularly in terms of magnitude of values. For instance, a common PBET for Greenfield projects and Interior Renovation Projects would be misleading as those two types of projects is completely different in many economic aspects. Therefore, a PBET should be clearly attached to a specific type of project, thus it requires the incorporation of historical data collected from previous projects of this type. The estimating template that is proposed in this paper, as a demonstration example, refers to projects of Interior Renovations of commercial buildings.

- The size of the projects that the PBET is applicable to. Small projects, e.g. one lab of 500-600 square feet (45-55 m^2) have an increased cost per square footage compared to that of a whole floor of 10.000-15.000 square feet (1.000-1.400 m^2) with the same analogy of work per area unit to be performed. This is due to the fact that there is a minimum cost in every project, e.g. for mobilization and minimum wages, which in small projects it makes up a large portion of the total cost. On the other hand, in large projects, fixed costs make up a much smaller percentage of the final cost and they are "absorbed" by the large area, thus, they do not affect the cost distribution. This phenomenon that was observed during the development and testing of the new PBET in the context of this paper was ascertained by Senior Estimators and multiple Subcontractors that were asked accordingly. For example, the mobilization cost (fixed cost) for Demolition Subcontractors is currently around $3.000, so for small projects this would constitute practically almost the whole Demolition cost, since, even if the work is done within one day or less, the cost remains $3.000, while the actual working cost based on the hour rates is much less. On larger projects however, the work could take one week or more, so the fixed costs on the first day would be a smaller part of the total final Demolition cost after the labor costs of the remaining days were

added. Therefore, collecting data from both small (less than approximately 2.000 square feet or 180 m^2) and large projects would affect the distributions and distort the final estimations.

- The market wherein the source projects where developed. Projects in different cities or regions, usually present different labor rates, material costs, etc. Therefore, source projects for creating a PBET should be, preferably, developed in a market with the same characteristics of the respective one to the project in hand.

- The time that the source projects were estimated or constructed. Given that projects' cost, such as material and labor costs are affected by several market fluctuations, including inflation rates, loan costs, etc., the latter need to be incorporated in the database in a way to constitute a sound basis of estimation. Therefore, the database should include source projects that were constructed in the near past (one to three years ago) and, moreover, it should be continuously updated with up-to-date projects, so as to follow the cost indexes fluctuations of the market.

After determining the type of the projects that are going to be used, data are collected from previous projects. The fundamental value that the estimations will be based on is the cost per unit of area (e.g. USD/square foot or Euros/m^2). Area refers only to the building's interior where most of the work is performed. Exterior areas where work, such as landscaping, might be performed are not patterned due to significant variations in different cases.

2.2 Trades Selection

After the Project Selection, the definition of the major trades that are going to be used is required. In order to maintain the simplicity of a PBET, a number of 15-20 trades that make up most of the project cost should be selected. This can be easily determined by calculating the average contribution percentage of each trade to the total project cost. Based on expert judgment and observation of the preliminary budget estimations of the previous projects available, any trade that contributes on average approximately more than 2% to the final cost, is considered substantial and should be included in the PBET. Still, this can vary based on the type of the project under examination. The average percentages of the contribution of the Trades used for the development of the PBET in the context of this paper were estimated with the use of data from previous similar projects, which are presented in Table 1.

Table 1: Average Contribution Percentage of the PBET Trades to the Final Cost of Interior Renovations of Commercial Buildings Projects

Concrete & Masonry	Millwork	Painting	Carpentry	Plumbing	Sprinklers	HVAC
2.3%	9.7%	2.1%	12%	7.5%	6%	22%
Site Construction	Demolition	Unistrut	Structural Steel	Roofing	Doors & Frames	Glass & Glazing
7.8%	2.9%	1.8%	2.4%	1.4%	2.1%	2%
Ceiling	Flooring	Lab Casework	Radiation	Site Work	Ceramic Tile	Electrical
2.7%	3.8%	5.6%	2.2%	3.9%	2.2%	20%

In order to maintain the simplicity of the template, an ideal situation would be that up to 20 Trades should make up more than 95% of the final cost of all the examined projects. Therefore, by picking up those trades, it is quite probable that in any project of this type, those trades will make up more than 95% of the total cost. The PBET that is presented in this paper, includes 21 trades, which constitute at least 96.4% of the total projects' cost that were used as data.

There can be exceptions for special trades that do not appear very often, but when they do, they affect the final cost significantly. A typical example of such a case is Radiation Shielding, which appeared in the analysis of the PBET that is presented in this paper only in 9 out of the 55 projects used, while the average contribution of this trade to the final cost was slightly more than 2%. Therefore, the trade's contribution is also an important criterion, even if the trade is not very common.

3. The Analysis

3.1 Defining the Distributions

The next step that follows Data Collection is the analysis which determines the Probabilistic Distributions that each Trade Sample Set is correlated with. There are several software solutions like Crystal Ball, Pertmaster and @RISK, that can facilitate such an analysis; the proposed PBET is developed using the Simulation Software @RISK. By inserting in an MS Excel spreadsheet the cost per area unit values for each trade and selecting "Fit Distribution", @RISK will try to match the given sample to a known Probabilistic Distribution. Moreover, since the data set represents the ratio of Cost / Area, which is consisted of two numbers both belonging in the Natural Numbers Set (cost cannot have a negative value in our case), it is reasonable to define the Upper and Lower bounds of all the distributions to be matched. Therefore, the values of "Zero" and "Infinity" are set for the Lower and the Upper Bounds of all the examined distributions, respectively. Figure 1 presents this step of the analysis where distributions and their bounds are selected.
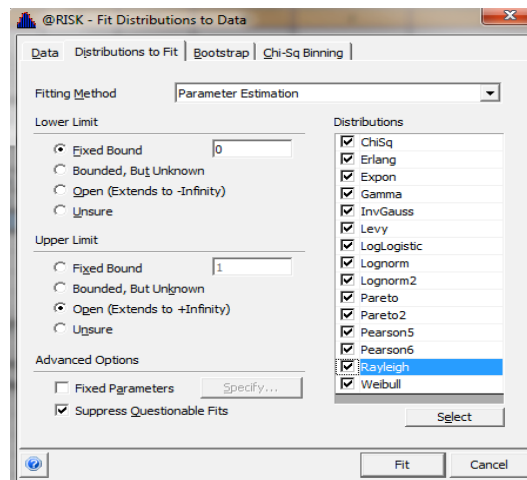

Figure 1: Fit Distribution Options

Normally, more than one Probabilistic Distributions may closely match the given sample, thus, it is the user's choice to select the appropriate one, based, primarily, on the Correlation Index and the P-P diagram, which indicate the better approximation of the sample to the distribution. Figures 2 & 3 present graphically the results of a fitted Gamma distribution and the respective P-P diagram with both indicating a good match of the sample values to the distribution (the fitted distribution becomes more reliable as the P-P Diagram follows the $f(x) = X$ function).

Once the distribution has been selected, the Mode value of the sample needs to be determined. The mode value represents the "normal" value of cost per area unit for the sample in hand with "normality" defined as the most frequent event. The determination of the mode value is essential, in order to set a point of reference in the sample and can be done through the respective operation in the software Figure 4 depicts the resulted mode value as well as the range for 95% certainty in the fitted sample.
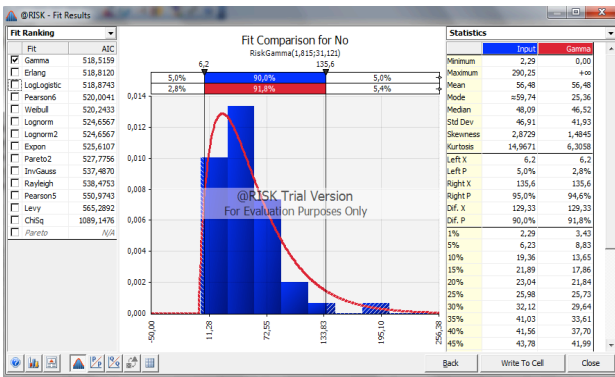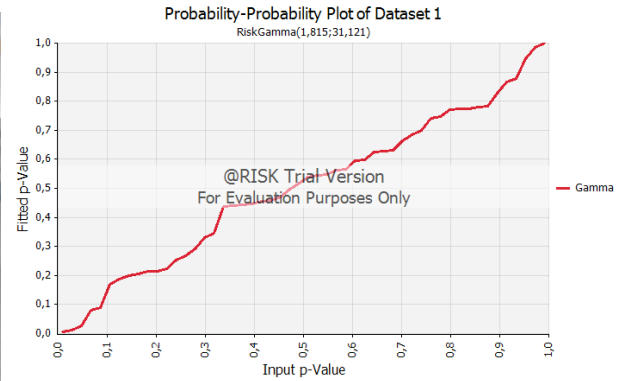
Figure 2: Fitted Probability Distribution

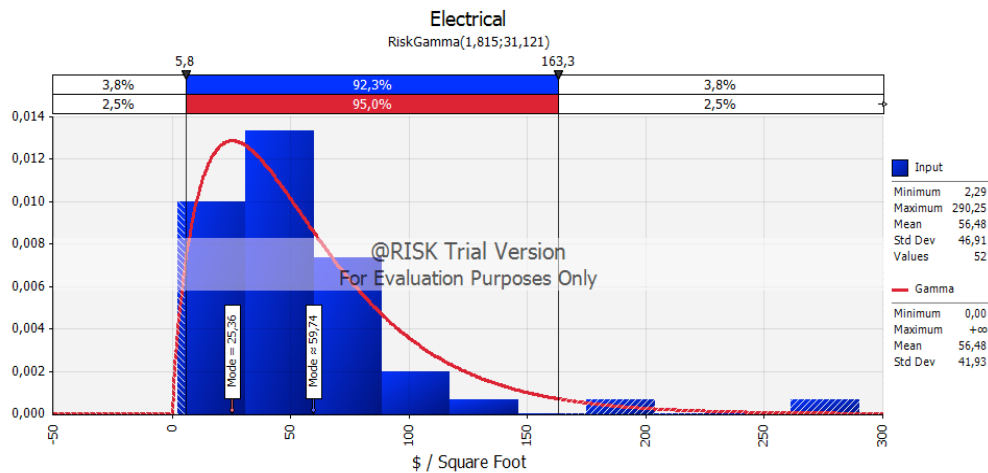**Figure 3: P-P Plot of Fitted Distribution**

Figure 4: Mode & 95% Certainty of Fitted Distribution

3.2 Defining the Trade "Intensity" Levels

The last and most important step of the analysis is the determination of the Trade "levels of intensity", i.e., the selection of the deterministic values that represent the cost/area depending on the intensity of each Trade. This determination is, practically, the process where the range of the levels above and below the mode value is determined. The number and range of these levels may vary depending of the sample Set range and the level of accuracy we want to achieve in the outcome. In this paper five levels are identified, namely "Intensive", "Very Intensive", "Extremely Intensive", "Light", "Very Light" and "Extremely Light", respectively.

The identification of the several levels' boundary values is feasible through the software's functions, which simplify the process, while remaining statistically acceptable. By using the "Fitted" distribution percentage (red line in Figure 4), instead of the "Actual Distribution's" percentage (blue line in Figure 4), to define the extreme boundary values, the 95% of the fitted distribution's values is set to be within that range; therefore those values that fall outside this range towards the maximum or minimum values of the sample belong to the "Extremely Intensive" and "Extremely Light", levels, respectively.

The next step is to divide the selected range to the number of levels that are selected for the analysis. To achieve that, a transformation of the distribution diagram is required, in order to create a handier diagram, yet retaining the accuracy of the original values. Therefore, a reformed warped diagram is created with the known values, i.e., the Mode and the Lower and Upper bound values. The mode value is set to the 50% of the X-axis, the Upper Bound is set to the 100% and the Lower Bound is set to the 0%. The rest of the distribution values to the left and to the right of the mode value are evenly distributed, in order to maintain the simplicity of the process. A second alternative would be to distribute the values according to selected levels of certainty, e.g. 65% (meaning that 65% of the sample values symmetrically to the Mode are within this range) and then set the bound values for the respective levels; however, this alternative was not applied to retain the simplicity of the estimating process. Figure 5 shows the reformed diagram using the first method, which corresponds to the distribution presented in Figure 4.
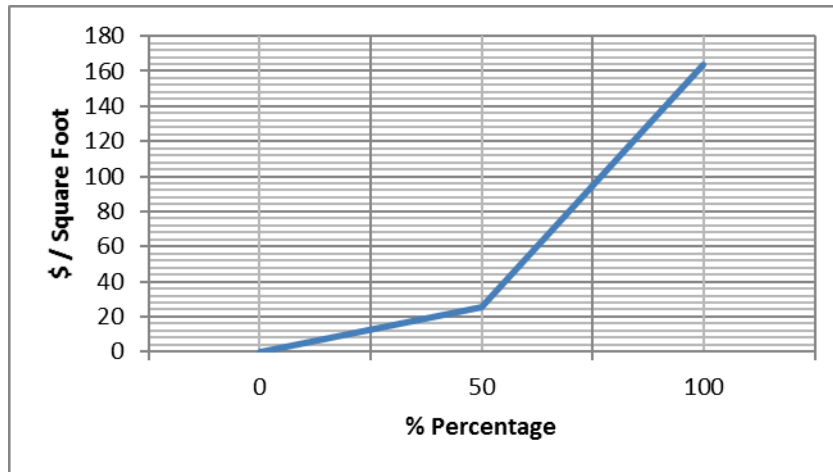

Figure 5: Reformed Percentage Diagram

Based on the diagram in Figure 5, it is easy to define the boundary values of the "Light", "Very Light", "Intensive", and "Very Intensive" ranges. Combining the values in Figures 4 and 5, the respective intensity level values are presented in Table 2.

Table 2: Final Intensity Level Values ($/square foot)

	EXTREMELY LIGHT	VERY LIGHT	LIGHT	NORMAL	INTENSIVE	VERY INTENSIVE	EXTREMELY INTENSIVE
0	5,8	12,32	19.12	25,36	71.34	117,32	163,3

4. Estimating Template User's Environment Example

The previous steps can be collectively presented in a user friendly MS Excel spreadsheet like the one presented in Figure 6.

As shown in Figure 6, the proposed, in this paper, approach for a preliminary budget estimation is based on the following input values: 1) building's area, 2) wage rate according to the applied type of labor costs, 3) taxation, 4) budget limits (optional), and 5) main project trades (intensity levels column).Through, data collection and analysis, as described in sections 2 and 3, the intermediate and final outputs are: 6) the cost per area unit, 7) the subtotals, 8) the best match to the estimated trade based on the available data, 9) the total material & labor cost per area unit, 10) the material total cost, 11) the total labor cost, and the 12) total project cost.

5. Conclusion

Accurate preliminary budget estimating is significant in any new construction project, since the output determines not only project feasibility and investment decisions, but also competitiveness, resources identification and allocation, and management plans. This paper introduces a Preliminary Budget Estimating Template (PBET) that aims to produce more accurate estimations by introducing a stochastic approach for the determination of the key cost elements of a budget under development. The approach utilizes empirical knowledge and data from previous experience to deliver a, deterministically expressed, estimated value of the total cost. After multiple testing in real life projects by comparing the final actual estimation cost of a project with the initial preliminary budget estimation of the same project, the accuracy of the template was more than 80% in almost every case, even when performing the budget just after a quick review of the construction drawings or a site visit. In conclusion, the presented PBET can be a useful tool in order to get a quick trustworthy preliminary budget of a project in a quick and economic way.

Preliminary Budget Estimation

General Project Specs

Square Footage	4,500	①
Wage Rate	Union	②
Tax Exempt	Yes	③
Available Budget	-	④

Apply Filter for Inactive Trades

Project Characteristics [5]

		[6] $/Square Foot	[7] Subtotal $	[8] Relevant Project
Site Construction	Light	4.00	18,000.00	13108-MSKCC Offices - carpet replacement
Site Work	Very Light	3.00	13,500.00	13246-Diagnostic Treatment Center
Demolition	Normal	6.00	27,000.00	13105 - Pharmacy Relocation Project
Concrete & Masonry	No	0.00	0.00	13252-Entrepreneur Lab
Unistrut	No	0.00	0.00	13162-Catherization Lab #1
Structural Steel	Normal	4.00	18,000.00	13252-Entrepreneur Lab
Millwork	Light	12.00	54,000.00	13217-Surgical Facility
Roofing	No	0.00	0.00	13113-LIJ-School of Medicine
Doors-Frames-Hardware	Normal	6.00	27,000.00	13236-Psychiatric Neoroscience
Glass & Glazing	Normal	2.50	11,250.00	13188-CT #1 and #2 Replacements'
Drywall & Rough Carpentry	Intensive	43.00	193,500.00	13157-Queens Imaging Centers
Ceiling	Intensive	5.00	22,500.00	13158-Lab A-22 Renovation
Ceramic Tile	Normal	2.00	9,000.00	13157-Queens Imaging Centers
Flooring	Very Intensive	17.00	76,500.00	13147-Renovation Dr. Cordasco Space
Painting	Normal	4.00	18,000.00	13215-Pulmonary Offices
Lab Case Work	Light	1.00	4,500.00	13157-Queens Imaging Centers
Radiation	No	0.00	0.00	13106-Emergency Dept. CT Renovation
Plumbing	Extremely Intensive	87.00	391,500.00	13137-New Chemistry Dept. Laboratory
Sprinklers	Normal	7.00	31,500.00	13158-Lab A-22 Renovation
HVAC	Intensive	65.00	292,500.00	13252-Entrepreneur Lab
Electrical	Normal	45.00	202,500.00	13246-Diagnostic Treatment Center
Contingency (%)	4.00%	56,430.00		
General Conditions ($)	$150,000			
Overhead (%)	2.00%	32,343.60		
Insurance (%)	1.50%	24,742.85		
Bond (%)	1.50%	25,114.00		

Final Estimated Cost

				$/Sqf
Total Estimated Cost:	$1,699,380.45	377.64 [12]		
Estimated Labor Cost:	$916,987.50	203.78 [11]	[9]	313.50
Estimated Materials Cost:	$493,762.50	109.73 [10]		

Figure 6: Pilot PBET environment

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