e-ISSN: 2618-575X

Available online at www.dergipark.gov.tr

INTERNATIONAL ADVANCED RESEARCHES
and
ENGINEERING JOURNAL

Journal homepage: www.dergipark.gov.tr/iarej

International Open Access

Volume 02
Issue 03

December, 2018

Research Article

An approach to preparing a bill of quantities

Murat Bikçe [a,*], Süleyman Göçer [a]

[a]*Department of Civil Engineering, Iskenderun Technical University, Hatay, Turkey*

ARTICLE INFO

Article history:
Received 19 March 2018
Revised 21 May 2018
Accepted 23 May 2018

Keywords:
Bill of quantity
Construction cost
Program

ABSTRACT

At the pre-design stage, it is essential for designers and property owners to have a rough idea regarding the material quantities necessary for construction as well as the building cost. To know these approximate values is of great importance in terms of the correct establishment of the financial model at the pre-design stage, the elimination of cash flow problems and the prevention of loss of national wealth. While calculating these values, approximate unit costs announced by the Ministry of Public Works and Settlement are used. In Turkey, the cost estimate at the pre-design stage is obtained by multiplying the total building construction area by the unit construction cost. However, it is generally accepted that this value is high in terms of free market costs. The purpose of this study is to prepare a program that can calculate approximate construction cost with unit workmanship prices in a specific region and approximate quantities including the minimum and maximum values of the material values by entering simple information about a planned RC building. Accurate cost estimation at the pre-design stage is proportional to the accuracy of the material metering ratios. The coefficients taken into account in this study have been checked and calibrated with a large number of projects, and it was observed that the samples containing the preliminary results of the study were compatible with the application project results.

1. Introduction

A bill of quantities (BOQ) is a detailed calculation of materials, structural elements and labor to identify the quantities by length, area, volume, weight and number of elements required to construct a building [1]. A BOQ of a reinforced concrete structure (RC) can be prepared on a project as well as on a finished structure by making certain calculations. Estimates are possible thanks to these calculations which are essential to see a general financial budget. Identifying the cost of a certain structure by looking at the architectural, RC and installation projects is called an "estimate", which is performed in two phases. The financial calculations before construction done on preliminary or final projects are called Estimate I, and the financial calculations to determine the cost of a finished structure are called Estimate II. Estimate I is approximate since it is calculated by looking at the BOQ on a project. To illustrate, although it changes depending on the country, manufacturer and specification accepted by the institution/organization, the amount of steel used for 1m^3 concrete may change between 80 to 120 kilos, so it is not possible to have exact numbers during project process. On the other hand, Estimate II is certain and does not change because it is calculated by looking at purchase documents and the attachment register recorded during construction as well as construction documents. That's why, the real cost of a structure is revealed after Estimate II.

Generally, engineers are faced with the question of construction cost without the land cost even before the preliminary projects and they are expected to answer this question just with the knowledge of approximate total building area and number of storeys. However, engineers avoid this question, as construction cost depends on several parameters such as region, workmanship, the quality of structure and material. In a study regarding the cost of construction, it has been aimed to estimate the construction cost with the functional element method [2]. In order to do that, the cost of mass housing projects whose bearing systems are reinforced concrete has been calculated and the regression analysis has been performed by using the available data. As a result of the studies, it has been concluded that using hybrid methods helps to get

* Corresponding author. Tel.: +90 (326) 613 56 00; Fax: +90 (326) 613 56 13.
E-mail address: murat.bikce@iste.edu.tr

better estimates and similar studies are necessary for different structure types. In another study, they have aimed to determine and compare the cost estimating performance of "construction unit price method" and "unit area cost method" [3]. In a study focusing on just cost calculation, 14 different cost estimating methods and softwares developed by different institutions in the world for pre-design phase have been systematically examined in terms of the parameters defining cost data, the databanks they use and the steps they follow, and the appropriate ones for Turkey have been determined [4]. However, variables such as the construction area, the storey height of the building, the number of storeys, basement floor and the type of exterior wall are the factors that significantly affect construction cost. Therefore, the need for a calculation method necessary for an accurate cost estimating in the pre-design phase has been a serious problem in Turkey. In the preliminary design stage, the bill of material calculations based on the amount of material to be sent to Unit m^2 have not been fully realized.

The studies mentioned above focus on only cost. What matters here is the values for the BOQ presented to engineers, because it may be more realistic to get better estimates with the unit price of the materials if the BOQ of a structure is available. Since this need is quite evident in the construction sector, a lot of websites offer approximate unit quantities for masonry and framed buildings without a change in order to do a practical calculation [5]. In this list, for an RC building whose construction site is determined, the fixed values are presented as follows: reinforced concrete (0.38 m^3/m^2), reinforcing steel (34 kg/m^2), formwork (2.6 m^2/m^2), supporting formwork (2.8 m^2/m^2), working scaffold (1.43 m^2/m^2), brick wall (0.15 m^3/m^2), interior plastering (2.4 m^2/m^2), exterior plastering (1.3 m^2/m^2), ceiling plaster (0.90 m^2/m^2), whitewash (3 m^2/m^2), tile-ceramic (0.3 m^2/m^2), wood (0.15 m^2/m^2), wooden window (0.12 m^2/m^2), oil painting (0.42 m^2/m^2), wooden roof (for 5 floors 0.25 m^2/m^2), metallic coating (for 5 floors 0.27 m^2/m^2), granolithic floor (0.90 m^2/m^2), glass (0.10 m^2/m^2). Also, the following acceptances are presented for a BOQ in this resource:

Levelling Area (A) = Granolithic Floor A.
Rubble A. = Lean Concrete A. = Mosaic A.
Roof Tiles A. = Roof Insulation A. = Wooden Roof A.
Ceiling Plaster = Ceiling Whitewash
Whitewash A. = Interior Plastering A.
Window Oil Painting A. = Window Woodwork A.
1 m^3 Concrete=7-8 m^2 Formwork
Reinforced Concrete Volume= 70 - 90 kg Steel
Window Woodwork A. = %75 - 80 Normal Flat Glass
Door Leaf A. = %25 Frosted Glass
Of all the Steel = %40 - 45 Thin, %55 - 60 Thick

Despite being an approximate calculation, it is necessary to check and prove if this list which presents fixed values depending on the construction site matches with the real values. At least having lower and upper limits regarding the units depending on m^2 may give an idea to engineers about the limits of quantities in construction.

The purpose of this study is to prepare an excel program to calculate the approximate construction cost in the pre-design phase of III-B type buildings with a height of less than 21.50 m^2, IV-A apartment type with a height of less than 30.50 m^2 and IV-C type concrete housings with a height of 30.50 to 51.50 m^2. In this program, material quantities are calculated roughly by entering the values pertaining to building floor areas, number of floors and other materials that comprise the structure.

2. Cost Calculation of a Structure

In Turkey, an approximate construction cost for public and private buildings is calculated mainly with two methods as pre-design and post-design calculations.

2.1 Cost Calculation Before Architectural, RC and Installation Projects

It is possible to calculate real-like costs without the land cost with some practical formulas if the total construction area is known. These formulas, however, vary depending on the related standards and regulations, time and country.

2.1.1 Public Buildings

Unit cost per m^2 of public buildings for the previous year is regularly announced every year. For instance, "Notice regarding the approximate construction unit costs to be used in the calculation of architectural and engineering service charge" was published in the Official Gazette no. 29679 of 9 April 2016 [6]. In the notice, cost per m^2 for III-B type buildings with a height of less than 21.50 m is stated as 750 TL for the year 2016. The cost of a building whose total closed area is known can be easily calculated for the year 2016 by multiplying it with the stated value. However, the general opinion is that the cost value calculated as mentioned is higher than the real structure cost (Figure 1). That's why, in public tenders, companies bid on the discounted values that have been calculated with this method.

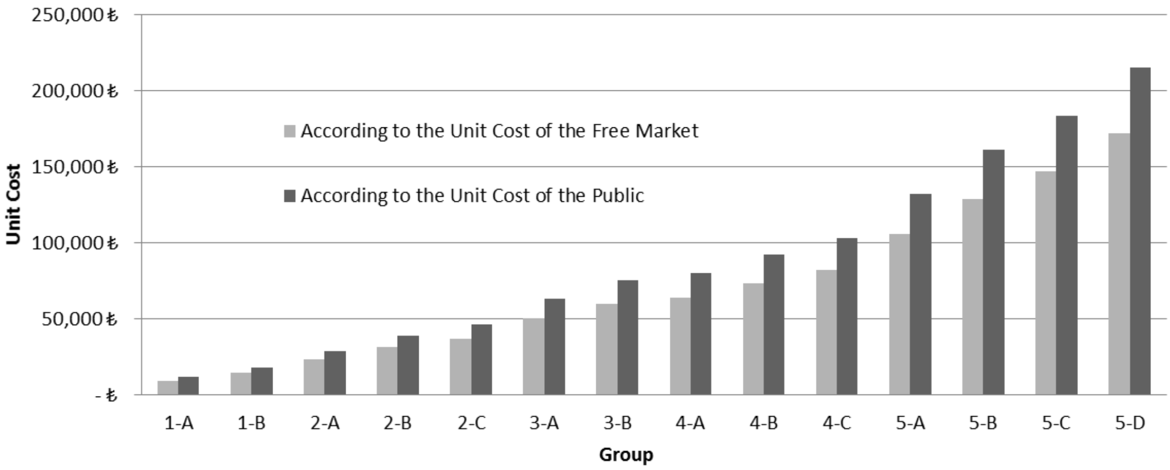

Figure 1. Sample construction cost for a 100 m^2 public and private building

2.1.2. Private Buildings

In the private sector, a technical worker often calculates construction cost of a projected building whose total construction area is known by using the unit cost per m^2 of the structures he worked on before. The exact cost of one or a few buildings in an area is calculated, and the received value is proportioned to the total construction area to get the cost for 1m^2 of the structure. At this point, it is possible to mention a huge gap regarding the cost of the structure.

As seen in Table 1, it is possible to get different values for 5 different buildings that were completed in 2006 with similar material and production properties in the same neighborhood [7].

Table 1. Properties and cost per m^2 of 5 different buildings completed in 2006 in the same neighborhood

Number of Floors	A Floor Area m^2	Total Construction Area m^2	Exact Construction Cost TL	Cost of 1 m^2 TL/m^2
5	186	930	272516	293.03
8	292	2336	720843	308.58
8	326	2608	834566	320.00
5	143	715	280654	392.52
5	195	975	312478	320.49
			Total	1634.62

Engineers may defend the received values with valid reasons, yet it is a fact that results differ by a third on m^2 scale. In order to avoid this, construction cost can be calculated by averaging the cost per 1 m^2 in a specific area. According to this, the average construction cost per 1 m^2 is obtained as 1634.62/5=326.93 TL/m^2.

2.2. Cost Calculation after Architectural, RC and Installation Projects

Since the BOQ of buildings with finished projects are calculated separately in static/RC analysis programs, the only thing left to do is to multiply each item by unit cost, which has been mentioned as Estimate I above. At this stage, because project deliverables are certain, estimates, BOQs, approximate calculation and comparative estimates can be prepared with certain programs or directly on the AutoCAD project [8]. A BOQ is also prepared for progress payments during construction as well as for the calculation of the exact cost at the end of the construction period. When quantities are itemized, it is easy to receive the construction cost by multiplying them by unit cost per m^2 [9]. However, unit costs per m^2 for public and private buildings differ in cost calculation.

2.2.1. Public Buildings

Every year, a book including current unit prices for construction and installation is published for public buildings, in which each item in a BOQ is presented separately.

2.2.2. Private Buildings

For private buildings, on the other hand, the technical worker obtains the costs by multiplying the received quantities by market unit prices.

3. Preparing a Bill of Quantities at Pre-project Stage

The purpose of this study is to prepare a BOQ at the pre-project stage. At least having lower and upper limits for materials in the units depending on m^2 may give an idea to engineers about the limits of quantities in construction. For practical reasons, the data wanted regarding the building has been kept minimum at the beginning (Table 2).

In this study, some practical acceptances have been made related to the ratios of the materials constituting the structural elements, because the project of the building is not ready. At the beginning of the study, in order to do a practical calculation, approximate BOQ unit values that are presented for RC buildings in the literature [5] and that match with the unit area of the building have been taken into account. It is necessary to check and prove if this list including fixed values regarding the total construction area matches with the values in real application projects. The material ratios taken into account in this study have been checked with the ones obtained from the BOQs of many projects. In this way, the coefficients used in the study have been calibrated (Table 3).

Since this study includes preliminary results of ongoing program-development studies, it contains important items of the building such as concrete, reinforcement and formwork. The previous values of the coefficients that have been used can be changed on the demand of a user. The depth and two dimensions of the foundation concrete can be obtained by multiplying them by certain coefficients depending on the basement floor area. The result of project calculation check and the comparison of error ratio are presented in Table 4.

If the BOQ of real application projects is between upper and lower limits of the values obtained in the program, it will mean that the program is close enough in reflecting the general supplies of RC buildings. In order to minimize the error ratio, calibrations have been performed by making comparisons with a lot of RC projects designed in accordance with the updated earthquake regulations. The cost results of the sample project can be seen in Table 5. The BOQ values obtained as a result of the analysis of the RC building can be counted as close enough to the upper and lower values received in the program which has been prepared in this study. It is not possible to expect the approximate results obtained in this study to match exactly because the projects of the RC buildings used here are not ready. The work on improving the unit coefficients has been going on.

Table 2. Data entry of the building

DATA TO BE ENTERED		
Constraints	**Lower Values**	**Unit**
Short Dimension	19.38	m
Long Dimension	19.38	m
Basement Floor Area	375.70	m²
Ground Floor Area	393.46	m²
Normal Floor Area	393.46	m²
Attic	393.46	m²
Number of Basement Floor	2	Number
Number of Ground Floor	1	Number
Number of Normal Floor	8	Number

Table 3. Unit material quantities for calculation and calculated values for the sample

	Material Quantity for 1 Unit			**Calculated Values**		
Manufacturing Type	**Lower Value**	**Upper Value**	**Unit**	**Lower Value**	**Upper Value**	**Unit**
Unreinforced Concrete	0.25	0.27	m³/m²	98.37	106.23	m³
Reinforcement Steel	24.00	27.00	kg/m²	9.44	10.62	t
Unreinforced Foundation Concrete	-	-	-	619.91	721.34	t
Foundation Steel	75.00	80.00	kg/m³	21.13	24.04	t
Unreinforced Concrete of Basement Floor	140.44	159.59	m³	140.44	159.59	m³
Basement Floor Steel	120.00	125.00	kg/m³	16.85	19.95	t
Formwork	2.80	3.00	m²/m²	1101.69	1180.38	m²

Table 4. Proportional comparison of structure material values of the real project and the results obtained in the program prepared in this study

PROJECT							
Structural Element	**Component Element**	**Unit**	**Value**	**Subvalue**	**Difference**	**High Value**	**Difference**
			A	B_1	$(B_1-A) / B_1$	B_2	$(B_2-A) / B_2$
Foundation	***Concrete***	*m³*	319.76	330.18	3%	347.56	8%
	Reinforcement	*t*	22.18	24.76	10%	27.80	20%
Basement Floor	***Concrete***	*m³*	138.37	131.63	-5%	149.77	8%
	Reinforcement	*t*	15.29	15.80	3%	18.72	18%
Ground Floor	***Concrete***	*m³*	89.19	86.89	-3%	93.84	5%
	Reinforcement	*t*	9.66	8.34	-16%	9.38	-3%
Typical Floor	***Concrete***	*m³*	82.61	84.74	3%	91.51	10%
	Reinforcement	*t*	8.08	8.13	1%	9.15	12%
Loft Floor	***Concrete***	*m³*	26.52	21.18	-25%	22.88	-16%
	Reinforcement	*t*	2.22	2.03	-9%	2.29	3%
Total Structure	***Concrete***	*m³*	1544.50	1527.69	-1%	1656.08	7%
	Reinforcement	*t*	142.08	146.04	3%	166.15	14%

Table 5. Cost including structure material results of the sample project

Component Element	**Quantity**			**Total Budget**		
	Subvalue	**High Value**	**Value**	**Unit Cost (TL)**	**Sub Account (TL)**	**High Account (TL)**
Concrete	1447.95	1575.84	*m³*	135.00	195,473.02	212,738.90
Reinforcement	139.83	159.55	*t*	2,370.00	331,390.19	378,139.58

4. Conclusions

This study includes the preliminary results of the work on the calculation of BOQs for RC buildings at the pre-project stage. This program which is needed by engineers to be used in practical calculations across the country can easily calculate approximate construction costs with material quantities obtained by entering the number of floors and floor areas of a structure along with the unit prices of workmanship and material in that specific area. The previous values of the coefficients that have been used can be changed on the demand of a user. As a result of the first analyses, the values obtained in the program have been found compatible with the results received from the BOQ of the real structure analysis. When the study is completed, all engineers will be able to benefit from it.

References

1. Birecikli, B.M., *Yapı Metrajı ve Maliyeti*. Eylül 2016, Türkiye: Birsen Yayınevi. p.535. in Turkish
2. Onur, L.U. and U.N. Baykan, *Yapı maliyetinin fonksiyonel eleman yöntemi ile tahmini*. e-Journal of New World Sciences Academy, 2009. **4**(4): p. 449-458.
3. Bayram, S., M.E. Öcal, E. Laptalı Oral, ve C.D. Atış, *Yapım maliyeti tahmininde birim fiyat yöntemi – yapı yaklaşık maliyetleri kıyaslaması*, Politeknik Dergisi, 2016. **19**(2): p. 175-183. in Turkish
4. Polat D.A. ve M. Çıracı, *Türkiye'de tasarım öncesinde maliyet tahmini için veri tabanı modeli*. İtüdergisi Mimarlık Planlama Tasarım, Eylül 2005. **4**(2): p. 59-69. in Turkish
5. İMO, [cited 2017 30 August]; Available from: http://bursa.imo.org.tr/resimler/dosya_ekler/e4e313a1f589c72_ek.pdf?tipi=84&turu=X&sube=0
6. Resmi Gazete, [cited 2017 30 August]; Available from: http://www.resmigazete.gov.tr/eskiler/2016/04/20160409-22.htm. in Turkish
7. Türk, K., [cited 2017 30 August]; Available from: http://eng.harran.edu.tr/moodle/moodledata/53/Ders_Notu/Yapi_Planlama_ve_Organizasyonu.pdf. in Turkish
8. Anonim, [cited 2017 30 August]; Available from: http://www.yapi.com.tr/urunhaberleri/com-otomatik-metraj-cozumleri-ile-metraj-hesabi-1-gune-iniyor_133264.html. in Turkish
9. Çevre ve Şehircilik Bakanlığı, [cited 2017 30 August]; Available from: https://birimfiyat.csb.gov.tr