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A building cost estimation model based on cost significant work packages

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Abstract

Purpose – The objectives of this paper are to discuss the constraints stemming from the unstructured nature of the cost estimation practice in Turkey and introduce a generic computer aided building cost estimation model based on a cost significant technique for Turkish construction sector public projects in its detailed design phase.

Design/methodology/approach – The research design was based on the simplified version of the bill of quantities method and a cost significant estimating model works on a cost database was suggested to overcome the problems. Underlying principles and basic steps of cost estimation based on cost significant work packages was explained by means of manual calculations.

Findings – In order to automate the manual building cost estimation process, the software based on cost significant work packages was developed.

Research limitations/implications – The software is currently in the testing phase and is being used for educational purposes. Making use of both public sector and current market prices in the cost estimation process, increasing number of projects stored in the database for more accurate results, estimating costs of different types of projects and calculating the cost significant value factor more precisely by using statistical techniques, those being employed by global cost models are suggested for future research.

Practical implications – As the number of the similar projects in database is increased, the accuracy of the cost estimation is also increased.

Originality/value – Estimators and graduate students can use the software to estimate building cost of public housing projects in its detailed design phase.

Keywords Cost allocation, Cost estimates, Computer applications, Construction industry, Turkey

Paper type Research paper

Introduction

Owing to the structure and physical characteristics of its products, the construction sector differentiates itself from the other sectors. Its objective is to get the highest productivity and quality within the scheduled time and the budgeted cost limits by utilizing the resources available. As the end product, namely the building, is unique and one of a kind, wide in scope and high in cost, creating a prototype is not only uneconomical but also impractical. Therefore, it is crucially important to produce a forecast of the probable total building cost; in other words "to estimate the building cost of a future project, before the building has been designed in detail and contract particulars prepared" (Ferry and Brandon, 1986; Seeley, 1983).

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In the globalizing construction sector, with the help of international partnerships and joint ventures, the number and size of projects are increasing, and the projects are getting more complicated and extensive. It is becoming more difficult to achieve the set objectives concerning the building costs. During the design phase, the probable building cost can be estimated using cost models based on traditional methods and techniques. However, accuracy of the estimation will depend on the level of the project data sources. Traditional building cost estimation methods have become ineffective in time, since projects have become larger, multinational and sophisticated. These methods have been replaced by computer-based practices, which are easier, time saving and have a more accurate estimate. The computer-based building cost estimation systems mostly rely on databases on which a great amount of project data is stored, processed and reported to users. This has positively affected the development of the building cost estimation practice that takes many parameters into consideration.

In order to reflect the reality and to get more accurate estimates, the building cost databases that will be used in the estimation practice should be reliable and up-to-date. Relational database management systems (RDBMS) and online virtual environments (VE) that supports data and information shared among users all over the world may be a solution to the building cost estimation problem.

Determination of the problem

Cost estimation can be made at different phases of the building production process, starting with the inception and feasibility of the project, continuing with the preliminary design and detailed design (design development) phases, and finally ending with the completion of the project. Concentrating on the cost estimation at every phase of the building production process provides opportunities for projects that can be built in compliance with cost objectives previously set.

The purpose of the cost estimating activities in the inception and feasibility phases is to determine the cost range with indications of quality or advice on owner's cost limits. Unit, cube or floor area methods may be employed. Cost planning in this phase refers to the process in which it is decided whether or not construction of the project is suitable under the prevailing physical and legal conditions. After the owner has decided to carry out the work, the cost limit is confirmed with the user's requirements, outline design and proposals. Approximate quantities based on assumed specs or cost of similar projects built previously may be used due to the lack of data for comprehensive cost estimation. At the preliminary design phase, a draft cost plan is prepared on the basis of a schematic design and statements of quality standards and functional requirements received from architects and engineers. Cost studies and checks are carried out during the detailed design and construction phase systematically to sustain the cost limits determined before. Data amount available that can be used for building cost estimating increases as the construction progresses. The most sensitive cost calculation can be made after the as-builds are drawn up at the completion of the project (Frank, 1994; Seeley, 1983; Killingsworth, 1988).

The cost data to be used during cost estimation should be suitable to the phase of the building production process, and it should be reliable and updated so that the cost estimation can reflect the reality. It is of greater importance in terms of the projects to be built within high inflation risk.

Construction companies bring together the cost data after the completion of contracts and settlement of final accounts generally. Historical cost data derived from similar projects provide feedbacks to assist future designs. It means larger construction companies has larger cost database. Periodically published cost indices, catalogues and some cost estimation software help professionals during building cost estimation process as well. Conversely, construction sector in developing countries, such as Turkey, suffers not only from lack of reliable and updated cost data but also inflation risk. Due to the competition and confidential nature, in-house cost data cannot be shared among construction companies. In order to make precise cost estimation there should be some tools, such as cost indices, catalogues and software. The only cost data that everyone in the Turkish construction sector can easily access is published annually by "Ministry of Public Works and Resettlement" in order to standardize public sector tenders. Computer-based applications in the Turkish market only help professionals prepare bill of quantities (BoQ) for tender documentation and monthly statements of ongoing projects, and calculate final accounts and variations between actual and estimated cost.

In order to overcome the above-mentioned limitations on estimating the building cost of public sector projects, a research project was carried out in Istanbul Technical University (ITU) with financial support of the State Planning Organization (SPO).

The BMBS research project

"ITU Construction Management and Building Cost Research Centre" has worked on studies about building cost since 1996. One of these studies was the BMBS research project. The motivation behind the research project was to develop a "Building Cost Information System" for the Turkish construction sector. The short-term objectives of the project were to collect and store all the available cost data produced for the Turkish construction sector in a relational database, process the data and prepare reports in order to present brief information that professionals, academics and students need (Orhon *et al.*, 1996). The research team has developed a software called "BMBS", which is the abbreviation for the building cost information system in Turkish. It works on a Progress™ relational database management system (RDBMS). The data structure of the BMBS software relies strictly on unit rates and analysis data published by the Ministry of Public Works and Resettlement. BMBS software has a series of modules that simulate a range of building cost estimation models for different phases of the building production process, such as unit method, elemental cost analysis, and cost significant work packages.

One of the modules of the BMBS software is the simulation of the building cost estimation model based on cost significant work packages (CSWP) in the detailed design phase. Simply put, BoQ and project data are entered and a query is run among similar projects in the database. Similar projects and quantities of cost significant work packages are listed for the user. As the quantities of the work packages are entered by the user, the estimated total cost of work packages is calculated for the project concerned. Dividing the estimated total cost of work packages by the cost significant value factor (CSVF), the total building cost can be predicted. The BMBS building cost estimation model based on cost significant work packages can be used in the detailed design phase.

The motive of development of such a module is to apply cost significance method to building construction. BRIDGET developed by Babtie, Shaw and Morton is the first successful application for predicting and controlling bridge construction costs using cost significance method (Horner *et al.*, 1990).

The objective of this paper is to discuss briefly the constraints stemming from the unstructured nature of the cost estimation practice in Turkey and introduce a generic computer aided building cost estimation model based on cost significant technique for the Turkish construction sector public projects in the detailed design phase. Prior to introducing the software, underlying principles of cost estimation based on cost significant work packages will be explained by means of manual calculations.

Estimating based on cost significant items

BoQ is the traditional method that is commonly used by construction companies to predict the cost of a project in the detailed design phase and throughout the construction. BoQ is one of the most important components of the tender documents along with technical drawings, specifications, conditions of contract, etc. Once a project is defined in detail, every item of work needed to complete the project is listed and priced by estimators.

An estimator should look for various factors that may influence the approach to pricing (Akintoye, 2000). For instance, the code of estimating practice by Chartered Institute of Building (CIOB) documents estimating functions those have to be followed through estimation and with other departments of the construction companies.

On the contrary, there is no guide to be followed in the cost estimation practice apart from in-house practices and experiences of the estimator in public sector tender procedures in Turkey. Pricing the items of work mostly depends on the owner of the project, either in the public or the private sector. In public sector tenders, contractors should calculate the tender price in accordance with the unit rates published by the Ministry. Alternatively, in private sector tenders, contractors could determine the tender price without fixed unit rate constraints. However, both procedures take considerable time to complete the list precisely and the operation is open to errors, if the estimator does not have any experience in pricing tenders. The list includes very large numbers of small items of work even for a small one-story housing project.

BoQ for building work is counter productive and leads to ambiguities and differences in interpretation, creating a potential for dispute. An acceptable level of simplification can be achieved through the aggregation of work items, presently required to be measured separately (Edwards and Edwards, 1995).

Horner and Asif (1988) identify characteristics of an ideal cost model as simplicity, flexibility, and generic relationships; in other words allowing successive refinement of one basic model and correspondence that is, a comparison of estimated and incurred costs. BoQ is based on standard methods of measurement, emphasizes building materials and components, and contains too much detail to effect rapid feedback that is essential for cost control.

Cost significant estimating is suggested to overcome the problem of pricing bulk numbers of small work items (Horner and Zakieh, 1993, 1995; Munns and Al-Haimus, 2000). Cost significant estimating is based on Pareto's principle. The principle established by an Italian Economist, Vilfredo Pareto, holds that 80 per cent of the effect is caused by 20 per cent of the causes. Pareto's principle, now commonly called the

80:20 rule in everyday business, refers to fact that 80 per cent is often achieved by the 20 per cent. As we concern construction business we can say "20 per cent of the work items contribute to 80 per cent of the total building cost".

The model

It is a well known fact that basic steps in developing a building cost estimation model based on cost significant work packages are:

- finding the cost significant work items in BoQ;
- grouping similar work items together to select work packages; and
- calculating a cost significance value factor (CSVF).

In developing the model, 21 bills from reinforced concrete-framed residential building projects were studied. State Statistics Institute (SSI) data were taken into consideration to determine the construction type to be used in the model.

Housing units occupy 85.01 per cent of the total number of buildings and 69.15 per cent of the total floor area (m^2) according to the results of the building construction statistics of the second quarter of 2003. It is equal to 68.85 per cent of the total buildings' value in monetary terms. On the other hand, 86.35 per cent of the units are built as reinforced concrete-framed buildings of more than four stories (State Statistics Institute, 2003a, b).

Finding the cost significant work items

In order to determine the cost significant work items (CSWI), 21 reinforced concrete-framed residential buildings, which have four or five stories are studied. Projects have four or mostly five stories and four units on one floor with a total floor area of 75-175 m^2. There is no elevator and no basement floor.

The classification system based on work items is used in order to price BoQ. The classification system is shown in Table I. There are 34 major code headings and each has a range of sub-codes of work items, which can be used in calculations. Unit rate analysis and unit price of each work item, including labour, material and equipment (if applicable) and contractor's mark-up are also given in the catalogue.

All of the bills had been prepared by different contractors using public sector tender procedures and priced with the unit rates published by the Ministry on the same year basis. Since, standard unit rates and work item analyses were used in pricing bills, there were no pricing differentiation and variations in developing model, except for some minor works that were not cost significant.

The cost significant items may be simply defined as the items whose value is greater than the mean bill value. The mean value is calculated as the total bill value of the project divided by the number of items contributing to total bill value. As the standard method of work item analysis is used and the same project type is studied, it is expected that similar work items will be determined as cost significant with only minor differences.

Table II shows analysis of 21 housing projects. The number of CSWI whose value was greater than the mean bill value was divided by the total number of work items. The bill value of CSWI was also divided by the total bill value. The average number of CSWI was 19.24, in other words 36.04 per cent, and the average bill value of those was 81.86 per cent. Although almost 80 per cent of the total cost was reached, work items should be grouped in work packages in order to reduce the numbers as to the 80:20 rule.

Table I.
The classification system based on work items

Major code headings and definitions	Work items	Sub-code range	
01	Excavation	14.001	15.018/3
02	Sand and gravel	15.140/2	–
03	Slab on grade	16.001	16.015
04	Reinforced concrete	16.022/1	16.059
05	Bore pile	16.060	16.067
06	Masonry	17.001	17.143
07	Brickwork	18.001	18.178/9
08	Concrete blocks	18.301	18.304
09	Demolition	18.181	18.194
10	Roof finishing	18.211	18.264
11	Expansion	18.351	18.384
12	Pot floors	18.321	18.330
13	Concrete piping	18.401	18.459/1
14	Insulation	18.461/1	19.084/1
15	Conc. and mortar add	19.087	19.103/4
16	Formwork and scaffold	21.001	21.068
17	Woodwork	21.126	21.281
18	Parquet, handrails, panels	21.286	21.313
19	Doors joinery	22.001	22.043
20	Windows joinery	22.045	22.079
21	Concrete reinforcement	23.001	23.015
22	Iron works	23.051	23.101
23	Iron door and windows	23.111	23.255
24	Flashing	24.001	24.064
25	Painting and varnishing	25.001	25.06433
26	Floor and wall finishes	25.081	26.661
27	Joints	27.101	27.105
28	Plastering	27.501	27.564
29	Mosaic and screeds	27.565	27.587
30	Glazing	28.001	28.099
31	Prefabricated construction	30.001	30.101
32	Door hardware	90.77301	90.77313
33	Window hardware	91.77351	91.77405
34	Furnishing	92.001	–

Setting the CSWP

CSWP are known as groups of similar work items that contain one type of material, use a single rate of measurement and provide a general description of the nature of the work involved in an activity.

CSWPs have also been set up on the basis of the work item unit rate analysis classification approach, established by the Higher Science Council of the Ministry. As shown in Table I, 34 major code headings contain a range of interrelated work items. Each work package was analyzed grouping similar work items in a separate package and setting the unit price of the package. If there was only one work item in the package, it was accepted as the unit price of the work package. If there was more than one work item in the work package, the unit prices of all the work items whose unit prices did not have a difference of more than 10 per cent were taken and then the mean value was calculated. The mean value calculated was accepted as the unit price of the

Table II. Analysis of 21 housing projects and calculation of CSVF

Column	No. of total work items 1	No. of CSWI in total 2	CSWI/WI (per cent) 3 = 2/1	Total bill value of CSWPs (TL) 4	Actual total bill value (TL) 5	(c_i) Total bill value of CSWPs/actual total bill value 6 = (4/5)	$(c_i)^2$ 7 = 6 × 6	Estimated bill value 8 = (4/CSVF)	Estimated bill value/actual bill value (TL) 9 = (8 − 5)	Estimated bill value/actual bill value (per cent) 10 = ((9/5)/5)
Project 1	53	20	37.74	10,202,444,892	12,268,193,324	0.8316	0.6916	12,455,045,580	186,852,256	1.52
Project 2	56	21	37.50	11,264,824,568	13,602,373,162	0.8282	0.6858	13,751,988,364	149,615,202	1.10
Project 3	57	17	29.82	12,369,937,292	15,698,080,587	0.7880	0.6209	15,101,099,238	−596,981,349	−3.80
Project 4	55	16	29.09	15,472,461,083	19,245,484,843	0.8040	0.6463	18,888,630,134	−356,854,709	−1.85
Project 5	53	21	39.62	10,247,805,271	12,116,119,387	0.8458	0.7154	12,510,421,090	394,301,703	3.25
Project 6	53	18	33.96	10,470,573,878	13,093,440,154	0.7997	0.6395	12,782,374,841	−311,065,313	−2.38
Project 7	53	19	35.85	10,927,088,521	13,403,731,953	0.8152	0.6646	13,339,683,481	−64,048,472	−0.48
Project 8	53	18	33.96	5,212,126,318	6,707,652,490	0.7770	0.6038	6,362,913,159	−344,739,331	−5.14
Project 9	53	18	33.96	13,597,359,735	16,878,660,940	0.8056	0.6490	16,599,524,630	−279,136,310	−1.65
Project 10	53	16	30.19	17,116,268,376	21,939,084,942	0.7802	0.6087	20,895,374,103	−1,043,710,839	−4.76
Project 11	53	20	37.74	10,396,901,569	12,507,790,339	0.8312	0.6910	12,692,436,401	184,646,062	1.48
Project 12	53	19	35.85	10,339,663,893	12,729,847,966	0.8122	0.6597	12,622,561,203	−107,286,763	−0.84
Project 13	53	20	37.74	10,766,418,438	12,940,770,764	0.8320	0.6922	13,143,539,004	202,768,240	1.57
Project 14	53	19	35.85	2,823,179,859	3,521,464,428	0.8017	0.6427	3,446,510,537	−74,953,891	−2.13
Project 15	53	20	37.74	5,513,920,805	6,684,466,095	0.8249	0.6804	6,731,340,936	46,874,841	0.70
Project 16	53	20	37.74	8,025,926,323	9,659,486,877	0.8309	0.6904	9,797,972,862	138,485,985	1.43
Project 17	53	20	37.74	10,340,450,539	12,400,345,887	0.8339	0.6954	12,623,521,533	223,175,646	1.80
Project 18	53	19	35.85	11,534,775,781	14,161,223,715	0.8145	0.6635	14,081,542,182	−79,681,533	−0.56
Project 19	53	22	41.51	10,689,625,174	12,382,651,778	0.8633	0.7452	13,049,790,534	667,138,756	5.39
Project 20	53	21	39.62	10,553,299,916	12,499,392,071	0.8443	0.7129	12,883,365,984	383,973,913	3.07
Project 21	53	20	37.74	10,416,829,222	12,611,789,363	0.8260	0.6822	12,716,763,887	104,974,524	0.83
Average	53.43	19.24	36.04			0.8186			−27,411,971	−0.07

work package. All the work items that had a difference in price of more than 10 per cent were accepted as a separate work package. The number of CSWIs of the 21 projects was between 16 and 21, and the mean was 19.24 as shown in Table II columns 1 and 2. Those items were summed up in 12 cost significant work packages as shown in Table III.

If there was more than one work item in a CSWP, and measurement units and/or dimensions of these work items were different, a conversion was made since it is accepted that work items grouped in a work package should use only a single measurement unit and contain one type of material. Twelve items shown in Table III were analyzed in detail in order to define the boundaries of each CSWP. For example, sub-codes were equalized to the most repeated sub-code in 21 projects for the thicknesses of different walls in "Masonry CSWP" of between 18.106 and 18.0711. The work item "18.0711" which was "8.5 cm half a brick wall" was accepted as a single CSWP using a square meter measurement unit. Since reinforced concrete in slabs and reinforced concrete in walls did not have different sub-codes and were treated as one in the classification system, reinforced concrete was accepted as a single CSWP using a cubic meter measurement unit. Rod and mesh reinforcement was also treated as one, using the tone measurement unit. Rod reinforcements in different diameters were equalized to the most repeated sub-code in 21 projects of "23.001" which is the "placement of rod reinforcement between 8-12 mm".

Calculating a CSVF

The proportion of the total value contained in the CSWPs is known as the CSVF, which is usually close to 0.8 (Horner and Asif, 1988). The optimum CSVF can be calculated using the equation:

$$\mathrm{CSVF} = \frac{\sum_{i=1}^{i=n} (c_i)^2}{\sum_{i=1}^{i=n} c_i}$$

where n is the sample size (number of BoQ), and c_i the total bill value of CSWPs for each BoQ divided by actual total bill value for each BoQ.

Table III. Cost significant work packages

	Work item sub-code (or code range)	Definition of CSWPs
1	16.0221	Reinforced concrete
2	18.106-18.0711	Masonry
3	21.011	Formwork
4	21.054	Scaffolding
5	21.210	Roofing
6	22.009-22.0511	Doors and windows
7	23.001-23.176	Reinforcement
8	25.005-25.0481	Painting
9	25.114-27.565	Flooring
10	26.071	Wall finishes
11	27.532-27.535	Wall and ceiling plasters
12	28.081	Glazing

In order to calculate the CSVF, total bill value of CSWPs (Table II column 4) is divided by the actual total bill value of each project (Table II column 5), and the value of c_i (Table II column 6) is found. According to the above formula, the square of c_i values (Table II column 7) is calculated and the mean value of c_i^2 is also found. In the model 0.8191 was calculated as the CSVF for 21 housing projects as shown in Table II.

As the total bill value of CSWPs for a project represents a constant proportion of the total estimated project cost, the total bill value of CSWPs is divided by CSVF to predict the estimated bill value (Table II column 8). The c_i values and the differences between the estimated and the actual bill values of each project are shown in Table II. The mean value of c_i is 0.8186, i.e. 81.86 per cent. It means the total cost of the 12 CSWPs shown in Table III contributes 81.86 per cent of the total building cost. The average of differences between the estimated and the actual bill value is -0.07 per cent. It means the estimated total cost of 12 CSWPs nearly equals the 81.86 per cent of the total cost of the projects.

The more projects in the database mean the more accurate CSVFs and cost estimates. As the number of similar projects in the database is increased, the accuracy of the cost estimation is also increased. It is accepted that there should be historical data gathered from at least 30 housing projects to get statistically significant results. Historical records of similar projects are the most important data for the model.

In order to automate the above-mentioned manual building cost estimation process, the module based on CSWPs was developed within the scope of the BMBS software. Steps of the cost estimation process are:

- entering project characteristics and BoQ;
- querying similar projects in the database;
- estimating cost; and
- revising cost estimation.

Building cost estimation process

Entering project characteristics and BoQ

The first step of the building cost estimation process is entering the characteristics of the project for which the cost estimation is to be made. The user should enter the characteristics of the project not only to make a query in the database to find similar projects but also to save and retrieve the estimation reports. The other important data that should be entered are the BoQ of the project. The total bill value of the project is used to calculate CSVF and quantities are used to enrich the database. The more BoQ in the database means the more accurate cost estimation. Data entered by the user are as follows:

- A *project number.*
- *Traffic code of the city* where the project is to be built.
- Short *definition* and *name* of the project.
- *Owner* of the project.
- *Date* of estimation.
- *Function code* of the project, which specifies the function of the project, such as housing, education, health, commercial, etc. This is chosen from among the function codes stored in the database.

- *Work type code* of the project, which specifies the work type such as construction of a new building, completion of unfinished construction, restoration, etc. This is also chosen from among the work type codes stored in the database.
- *Total construction area* and *number of stories* of the project; both can be inserted as just a value or value range.
- *Structural system code* of the project, chosen from among the structural system codes stored in the database.
- *Type of unit price,* the code specifying whether the cost estimation is to be updated with the public sector or current market prices (system only works with public sector prices for the moment).

Database query

Once the user enters characteristics and BoQ of the project, a database query runs. Projects, which have similar characteristics with the project concerned, are chosen and a project list is reported for the user. The number of projects in the list will be different according to the data entered and amount of projects stored in the database.

The user should evaluate the project list by examining whether the characteristics of the projects reflect the project concerned or not. If the user believes that the number and characteristics of the projects in the list are not sufficient or any of the project listed will result in an inaccurate estimation, then the user should modify the data entered to extend or narrow the database search.

Building cost estimation

As soon as the user accepts the project list, the cost estimation starts. CSWPs with the codes of the CSWI and their updated unit prices are reported for the user. The user should only enter the quantities of CSWPs listed on the screen.

The quantities of CSWPs, i.e. group of CSWIs, can be measured either automatically from CAD drawings by means of electronic tablets or manually with traditional measurement rules.

The quantities of CSWPs entered are multiplied with the updated unit price of each work package and then the updated work package cost is calculated. The sum of the cost of all work packages will show the total estimated cost of the CSWPs.

In the meantime, the percentage of the total estimated cost within the total bill value is calculated on the basis of the projects listed. It can be used as the CSVF. The total estimated cost of the CSWPs is divided by the CSVF to arrive at the estimated total building cost of the project concerned. The users could use their own CSVF or the calculated one.

Revision of the project cost estimated

The first estimation process presents a base value for the user to compare the project's budget and the total estimated building cost. By the trial and error method the user could make more estimations so as to arrive at the most convenient one. The user either modifies the characteristics of the project on the query or quantities of the CSWPs listed. All the estimations are stored in the database for future reference.

Testing the model

In order to test the model, the cost estimation process was run for 20 different reinforced concrete-framed housing projects, which will be built in Istanbul by means of public sector tendering procedures. The total construction area of the projects was between 1,000 and 1,500 m^2 and the number of stories was between 4 and 5. Different contractors priced BoQ using the work items unit rate analysis published by the Ministry. It should be noted that projects that had been used in the development of the model were not used in the testing process.

In the testing process, cost estimation steps of the model were followed up. Characteristics of each project were entered as a new housing unit. As the database query was finished, CSWPs and unit prices of them were listed in accordance with the characteristics previously entered by the user. The cost estimation steps were repeated for all 20 projects. The test results of the total bill value of CSWPs, the actual total bill value, and the total estimated bill value of the 20 projects are shown in Table IV.

Differences between the total estimated bill value and the total actual bill value of the projects scattered among −16.60 per cent and +8.58 per cent. However, mean value −5.01 per cent indicates that difference between the total estimated bill value and the total bill value of 20 projects are acceptable. Meanwhile, the total bill value of CSWPs represents 77.80 per cent of the total bill value as we concern 20 projects.

The more projects in the database means the more accurate CSVF and cost estimate. As the number of the similar projects in database is increased, the accuracy of the cost estimation is also increased. There should be historical data gathered from at least 30 housing projects to get statistically significant results.

Conclusion

It is a well-known fact that updated and reliable databases and information systems that support estimators are needed to make accurate cost estimation for different phases of the building construction process. Recent developments in information and communication technology enable to the development of such kinds of tools. However, the most important matter in cost estimation is the simplicity and applicability of the system to the factual cases. Cost estimation systems must be simple, reliable, flexible and convenient to the nature of the application area.

There are also some constraints stemming from the unstructured nature of the cost estimation practice in Turkey, such as a lack of guides and catalogues to be followed in cost estimation practices, insufficient cost data collection mechanisms, high inflation risk, etc. In public sector tenders, contractors should calculate the tender price in accordance with the unit rates published by the Ministry. Estimators mostly use the BoQ method in pricing tenders. It takes considerable time to complete the BoQ precisely, and the operation is open to errors if the estimator does not have any experience.

In order to overcome limitations on estimating building costs of public sector projects, a research project was carried out in ITU. Computer-aided cost estimation systems have been developed for different phases of the building construction process. The building cost estimation model based on cost significant work packages is the simplified version of the BoQ method. It is developed for public sector projects in the detailed design phase.

Table IV.
Test results of 20 projects

	Total bill value of CSWPS (TL)	Total actual bill value (TL)	Total estimated bill value (TL)	Difference (TL)	Difference (per cent)	Total bill value of CSWPs (per cent)
Project 01	6,832,892,888	8,860,727,835	8,341,952,006	−518,775,829	−5,85	77,11
Project 02	2,103,589,115	3,069,516,654	2,568,171,304	−501,345,350	−16,33	68,53
Project 03	11,819,080,800	13,777,049,479	14,429,350,262	652,300,784	4,73	85,79
Project 04	1,884,766,230	2,558,076,366	2,301,020,913	−257,055,453	−10,05	73,68
Project 05	17,149,465,129	23,235,949,110	20,936,961,456	−2,298,987,654	−9,89	73,81
Project 06	2,526,989,735	3,329,252,569	3,085,080,863	−244,171,706	−7,33	75,90
Project 07	1,059,588,594	1,349,212,927	1,293,601,018	−55,611,909	−4,12	78,53
Project 08	1,615,188,351	2,024,338,529	1,971,906,179	−52,432,350	−2,59	79,79
Project 09	1,406,537,097	1,705,185,956	1,717,173,845	11,987,890	0,70	82,49
Project 10	2,900,588,901	4,245,786,124	3,541,190,210	−704,595,914	−16,60	68,32
Project 11	5,875,321,406	6,836,815,178	7,172,898,799	336,083,621	4,92	85,94
Project 12	1,485,125,437	1,904,997,316	1,813,118,590	−91,878,726	−4,82	77,96
Project 13	3,275,202,758	3,682,446,936	3,998,538,344	316,091,409	8,58	88,94
Project 14	5,432,481,068	6,844,309,444	6,632,256,218	−212,053,226	−3,10	79,37
Project 15	2,161,413,043	3,032,561,787	2,638,765,771	−393,796,016	−12,99	71,27
Project 16	3,837,983,533	4,433,638,114	4,685,610,467	251,972,353	5,68	86,57
Project 17	4,450,178,156	5,747,337,929	5,433,009,590	−314,328,339	−5,47	77,43
Project 18	14,967,005,340	20,597,465,710	18,272,500,720	−2,324,964,990	−11,29	72,66
Project 19	2,368,657,619	2,958,771,630	2,891,780,758	−66,990,873	−2,26	80,06
Project 20	1,559,204,566	2,167,130,533	1,903,558,255	−263,572,278	−12,16	71,95
				Mean (per cent)	−5.01	77.80

The software is currently in the testing phase and is being used for educational purposes. There are some future works that should be made:

- making use of both public sector and current market prices in the cost estimation process;
- increasing projects stored in the database for more accurate results;
- estimating costs of different types of projects, such as commercial and educational buildings; and
- calculating the cost significant value factor more precisely by using statistical techniques, those being employed by global cost models.

References

Akintoye, A. (2000), "Analysis of factor influencing project cost estimating practice", *Construction Management and Economics*, Vol. 18 No. 1, pp. 77-89.

Edwards, P.J. and Edwards, M. (1995), "A price-rationalized approach to item separation in the measurement of concrete work", *Construction Management and Economics*, Vol. 13 No. 6, pp. 485-91.

Ferry, D.J. and Brandon, P.S. (1986), *Cost Planning of Buildings*, Collins Professional and Technical Books, London.

Frank, J. (1994), *Contract Administration and Practice*, B.T. Batsford Ltd, London.

Horner, R.M.V. and Asif, M. (1988), "Simple models for estimating and controlling project costs", *Proceedings of the 9th World Congress on Project Management*, Glasgow, Vol. 1, pp. 95-105.

Horner, R.M.V. and Zakieh, R. (1993), "Beyond BRIDGET – an integrated model for estimating and controlling reinforced concrete bridge construction costs and durations", *Highways and Transportation*, Vol. 40 No. 11, pp. 11-14.

Horner, M. and Zakieh, R. (1995), "Characteristic items – a new approach to pricing and controlling construction projects", *Construction Management and Economics*, Vol. 14 No. 3, pp. 241-52.

Horner, R.M.V., Murray, M. and McLaughlin, A. (1990), "BRIDGET – a cost estimating suite for highway structures", *Highways and Transportations*, Vol. 37 No. 5, pp. 14-88.

Killingsworth, R. (1988), *Cost Control in Building Design*, R.S. Means Company Inc., Kingston, MA.

Munns, A.K. and Al-Haimus, K.M. (2000), "Estimating using cost significant global cost models", *Construction Management and Economics*, Vol. 18 No. 5, pp. 575-85.

Orhon, I., Giritli, H., Tas, E. and Yaman, H. (1996), "Developing a building cost information system based on computer in the Turkish construction sector", unpublished final report of the research project supported by the State Planning Organization and Istanbul Technical University Research Fund, Istanbul.

Seeley, I.H. (1983), *Building Economics*, The Macmillan Press Ltd, Basingstoke.

State Institute of Statistics (2003a), available at: www.die.gov.tr/ENGLISH/index.html

State Institute of Statistics (2003b), available at: www.die.gov.tr/ENGLISH/index.html