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AGATA CZARNIGOWSKA*

UNIT RATE-BASED COST ESTIMATING – INPUT AND METHODS

UPROSZCZONA KALKULACJA KOSZTU BUDOWY – PODSTAWY I METODY

Abstract

The paper investigates the so-called "simplified methods" of construction cost estimating: from the simplest single-rate estimates to complex elemental and feature-based cost analysis. Method databases of recorded or calculated unit rates and a wide choice of data manipulation techniques, such as intuitive or mathematically supported case-based reasoning, statistical inference and non-parametric modeling are looked at. The consequences of using input from real-life projects and uniform purpose-made calculations (such as those published in Polish pricebooks) are also analyzed.

Keywords: cost estimate, construction cost models, case-based reasoning, construction price books

Streszczenie

W artykule przedstawiono charakterystykę tzw. uproszczonych metod kosztorysowania wartości robót budowlanych: od najprostszych, wykorzystujących pojedyncze wskaźniki, po rozbudowane kalkulacje w rozbiciu na elementy, oparte na intuicji eksperta, wnioskowaniu na podstawie przypadków oraz modelach parametrycznych i nieparametrycznych opartych na obszernych bazach danych. Rozważono konsekwencje opierania się na danych kosztowych faktycznie zrealizowanych przedsięwzięć (pochodzących z indywidualnych baz danych) oraz kalkulacji modelowych, pozbawionych indywidualnych cech (przygotowywanych przez wydawców informatorów cenowych).

Słowa kluczowe: szacowanie kosztów, modele kosztów budowy, wnioskowaniu na podstawie przypadków, informatory cenowe

* Ph.D. Agata Czarnigowska, Department of Construction Project Engineering, Faculty of Civil Engineering, Lublin University of Technology.

1. Introduction

Polish handbooks on construction cost estimating provide the reader with little information on how to prepare a construction cost analysis, other than in the case os a detailed one, based on exploring resources required for each particular construction operation – in terms of their direct and indirect costs and allowance for the contractor's profit. All other methods of cost estimating are generally called "simplified methods" (unit rate or unit cost methods) and described on one half page of text, more or less in this form [12, 14, 16]:

The total price for constructing a built facility or executing a defined scope of works is to be calculated as a sum, item by item, of products of the item's quantity and its unit price, plus the value added tax, according to the following formula:

$$P = \sum_{i=1}^{n} p_i q_i + T , \tag{1}$$

where:

- P – the total price to be paid to the contractor,
- i – the number of the priced items, $i \in <1, n>$,
- q_i – the quantity related with the item,
- p_i – the unit price of the item,
- T – the amount of value added tax calculated in accordance with applicable regulations.

The unit price, p_i, may (or sometimes: is to) comprise all direct costs (labor, material, plant), and a profit markup per unit of the cost plan item. The scope of work covered by an item and the way of calculating unit prices is to be agreed individually.

The problem with dismantling the analysis into useful items and ways of calculating reliable case-specific unit rates is left unexplored. The handbook refers to overall experience on local conditions [16], the possibility of using the planner's own databases or construction pricebooks, which are available on the market, or resorting to negotiations with potential contractors [12, 14].There is no advice on how to manipulate available data in order to arrive at a reliable estimate. It can be argued that Polish construction estimation handbooks use the term "simplified method" to cover any non-resource-based method of preparing cost analyses at all consecutive stages of the project:

- the project owner's cost estimates for early feasibility studies and business plans,
- design stage which analyzes related with cost checks and cost engineering aimed at optimizing designs with respect to the owner's economic objectives,
- the contractor's cost plans other than those based on resource analyses.

The paper aims to review the techniques of construction cost estimates presented in various related handbooks. The consequences of using input from real-life projects and uniform purpose-made calculations (such as those published in Polish pricebooks) are analyzed together with the necessary scope of adjustment of the estimate to the particularities of the new scheme. In the following text, cost estimating or cost planning will refer to the methods of estimating the price likely to be paid to the contractor – so it is the costs as seen from the project owner's point of view.

2. The stages of construction cost planning and related cost models with regards to' level of detail

The level of detail and accuracy of cost plans is related with the development of its input – the designs and other project information, as used with the selection of a procurement strategy. Table 1 presents these relationships.

Table 1

Design stage-specific cost plans, based on [5, 6]

Design stage		Cost plan type (aims)	Main decisions at this stage (examples)
Briefing	Inception and feasibility	Cost brackets (set the budget's upper limit)	Go/no go
Sketch plans	Outline proposals	Group elemental cost plan (confirm the budget)	No. of storeys, appearance, layouts, frame type
	Scheme design	Detailed elemental cost plan (set cost targets for the elements)	Technological solutions of main elements (e.g. brickwork or cladding of ext. walls), type of finishes, performance requirements and specification for services
Working drawings	Detailed design Production information Bill of quantities	Cost checks (confirm cost targets, optimize design decisions)	Refine technological solutions, select materials, define details and construction methods. Revise previous decisions if necessary. Prepare for tender.

2.1. Cost estimate at Feasibility stage

Before the owner commits to a design, he/she needs to calculate if the project is even worth considering – is it likely to be affordable or profitable? At this early feasibility stage, the likely construction cost is just one item in the list of total project cashflows that need to be estimated. A rough prediction is to be made, but this rough prediction will be treated with all respect – as the basis of the go/no go decision and will also be used for setting the upper limit of the budget [5, 6, 15]. The input available for this initial estimate is usually limited to the owner's assumptions on function, size, standard, location and foreseen length of time for the construction. At this stage, the estimate of likely cost brackets are usually based on information on how much similar projects were in the near past. The estimate is usually given as a single-rate or cost brackets of e.g. total construction cost per m^2 of usable floor space, or per functional unit related with occupation type – e.g. per bed in a hospital. It should be clear what, in terms of scope, is covered by this estimate – so that missing items of investment outlays (such as e.g. external works) could be then added as required [5]. As the estimate is meant for a future project, it needs to be adjusted to that time (by means of extrapolated price index), and for location (location indices, as prices of construction works usually differ region to region or city to city) [5, 6, 15].

2.2. Cost planning at Sketch plan stage

If the project owner has decided to start the design phase and the cost limits have been set, concept drawings can be developed. The exact location is decided, so foundation type, local planning restrictions, or the scale of external works can be taken into account. A number of shape plans and storey numbers can be worked out, and estimates will be required to provide an insight into cost effects of these proposals. These outlined cost plans are needed to confirm that the recommended solution meets the client's business objectives. The solution considered best is then developed into scheme of designs, and elemental cost plans state how much money should be spent on each functional element [5]. At this stage, the cost plans obtain a structured, element-related form, and costing is based on detail cost information derived from a number of similar schemes completed in the past. Elements are defined as components of the building which fulfill a particular function – regardless of their design or material [5]. Analysis carried out at this stage is based on knowledge and on cost distribution of similar buildings, and elemental rates per m^2 of e.g. gross internal floor space or elemental rates per unit of approximate quantity, as e.g. per m^2 of roof [6].

Using figures from other projects which are not identical with the considered one implies that a lot of adjustments will need to be made. Among them, preliminaries and overheads which represent the financial implications of the construction company managing the project need to be dealt with, with due care, due to their being highly case-specific, not directly related with design decisions, and the main area of variability between competing contractors [6]. Moreover, price and design risks need to be included in the plan: the former related with unknown market conditions at the moment of tender, and the latter with uncertainty of further development of the design.

2.3. Cost plans at the stage of Working drawings

This stage of design works produces complete information for constructing the facility. The task of the cost planner is to check if detailed material and technological solutions proposed by the design team fit the budget, and provide advice in this respect. If no solution can be found within cost targets, it may be necessary to revise assumptions and return to previous design and cost planning steps [5, 6]. The source of cost information may be derived from detailed cost plans and bills of quantities from past projects, but also from a direct market survey on the prices of materials or services of specialized subcontractors. Contingencies and allowances for the expected contractor's preliminaries and overheads are being further adjusted as there is more reliable information of the likely market condition – the tender date is closer, so forecasts becomes more accurate.

3. Cost data

Whatever a cost analysis' level of detail, and whatever the stage of cost planning, the crucial thing is to have the reference: prices of possibly large set of similar projects/elements/cost plan items. These prices are either based on historical cost data, or on real-life cases coming from winning contractors' bids (priced bills of quantities), or pricebooks of calculated unit prices. As this original input is provided in a great detail (as particular construction processes and their resources) and very case-specific, the data needs to be artificially aggregated and processed to suit the needs of earlier stages of project using planning and design of schemes that are considered of similar character.

The data needs to be prepared in a standardized format. A description of the approaches to the cost plan breakdown structure and the advantages of developing standard classification of construction estimate items were broadly discussed in [3, 17].

3.1. Historical cost data

If historical cost data is to be used as a basis for future cost planning (analyzing cost trends and forecasting, comparing and balancing costs of different designs) it is worth considering that [5, 6, 15]:

- case-specific local conditions reflected in historical data should be excluded as it would not relevant to the analyzed case, and replaced with an allowance for local factors for the new facility,
- historical figures need adjusting for time-related inflation.

Some of these adjustments may be carried out using compiled indices provided by pricebook publishers or statistical offices, whereas others may require field investigation and considerable professional judgment to reflect differences between a given project and the reference project from the database. Whatever the method, processed data is less reliable. Construction cost information systems based on historical data that adjust their case-specific input to mean location and to a common date, thus depriving them of specific character and facilitating data manipulation, such as BCIS [6] do exist, but these individual owner's or contractor's databases would most probably contain unprocessed records.

Using real-life bids as a source of cost information, does however, have further drawbacks. The higher the level of detail of the analysis to be made, the greater the number of samples of "similar" cases in the database, and the greater the degree of variation in unit prices offered for the item in historical records [5, 6]. However, this is not only due to design variations. Rates in the contractor's original priced bills of quantities are not true selling prices – they are the result of breaking down total prices into items required by the addressee of the calculation. As these items are not thought to be sold separately, an accurate division of cost between items would be a wasted effort for the contractor. To improve their cash flows, contractors tend to inflate the prices of items which are to be executed first, and deflate the prices of items scheduled later, which causes price distortions that cannot be automatically dealt with. Similarly, depending on the contract conditions, the items considered related with higher risks may be those which have been priced higher – and the perception of risk is individual. The method of apportioning profit, preliminaries and overheads to the items is contractor-specific: some of them may be included in item unit prices, and some shown separately (as e.g. required by the standard formats of cost breakdown structure [3]. It should also be considered that real-life bid totals “represent the socially acceptable price rather than a scientific appraisal of resource needs of the project” [5, 11].

Historical databases may contain thousands of records, enabling statistical analysis and data mining in search of correlations between project qualities and construction prices. This is potentially extremely useful in the process of adjusting estimates in the process of case-based reasoning and selecting economical design solutions.

3.2. Calculated rates

Polish pricebooks contain predominantly calculated rates – based on the publisher’s detailed resource-based analyses [3, 10, 17]. These are compiled using average, minimum and maximum resource prices established by the publisher in regular market surveys, the catalogues of “economically justified and average” resource consumption information (part of which is of purely historical value) and the personal experiences of estimators. The entries are thus regularly updated so, timewise, they by nature already brought the same datum. Pricebooks contain calculated unit prices and rates on a variety of aggregation levels ranging from construction operations to whole buildings.

All calculated unit prices and rates contain overheads and profit markups. These are based on percentage rates being average, minimum and maximum overhead and markup rates declared by contractors – respondents of the survey. Considering that the respondents may not be fully aware of what the overheads are, or use a variety of methods for incorporating them into their cost plan [13], and that the overheads are naturally case-specific, the declared rates may be far from being reliable. Besides, the same overheads and markup rates are used for calculating unit prices of particular operations and all rates of elements/BQ items of schools, hospitals, individual houses, parking lots and industrial plant buildings. Therefore, if they are to be used in calculations, they should be treated in a similar way to the rates based on historical records of actual projects: adjusted to case-specific location, construction time and specific conditions. It might be reasonable to analyze the “objective” calculated direct costs first, and then deal with case-specific overheads and profit costs separately. However, extraction of this case-specific portion of unit rate/price is usually difficult, as not all publishers show the amount or percentage of overheads per item, but instead sticking to all-in values [3].

Unit rates and item prices calculated this way are, theoretically, deprived of individual character and “location neutral”, so need less processing if they are to be used as a basis for new project estimates. Being based directly on the cost of resources and prepared in a uniform way, they may be considered reliable by not being distorted by the speculative assumptions of the contractor highlighted in the previous chapter, and representing “a justified value”. However, as such, they may have little in common with the real market prices the planner is aiming to use to carry out the estimate.

The number of reference buildings in databases are seriously limited (e.g. slightly over one hundred entries for buildings per a SEKOCENBUD BCO pricebook issue), though the publishers take care to provide data on at least a few buildings of the same function in order to enable a comparison. In contrast, historical cost databases as BCIS [5, 6] may contain thousand entries and are expanded every year by new entries.

4. Using the cost data

Large samples of uniformly prepared and reliable cost data are the basis of any "simplified method" of cost planning. Cost data can be approached as deterministic values (with calculations being usually repeated to allow for "most probable" "optimistic" and "pessimistic" scenarios to allow for uncertainty inherent in any projects), as random variables (with estimated distribution parameters and possibility of using simulations to support concusions), or fuzzy numbers.

The earliest estimates of construction cost brackets are prepared predominantly on the basis of simple statistical inferences, therefore deductive or correlation-based models. As only a few qualities of the project are defined at this stage, the model can be neither complex nor accurate. As the design process develops, more project qualities have to be considered with respect to their impact on construction cost, while simple statistical models like regression prove inadequate: the available sample of comparable buildings is usually too small and the number of potential independent variables too great to construct a reliable classical multifactor regression model. With a sufficiently large number of samples, other regression techniques such as neural networks [8, 9] or support vector machines [9] prove more robust.

However, there is usually a very limited number of available buildings comparable to the one analyzed. Therefore, the most frequent way of making cost estimates is intuitive case-based reasoning. The planner extracts a "proven" cost plan of a similar project completed in the past (or more than one), and attempts to reuse their cost plan adapting it to the analyzed case using simple calculations (interpolations), data from other similar cases and professional judgement to asses e.g. how a larger number of storeys or different type of footing affect the likely cost [6]. This method of natural reasoning has been, relatively recently, used in machine learning: a new problem can be solved by retrieving one or more previously experienced cases, reusing them to provide a solution, revising the solution, and retaining the new experience by incorporating it into the existing knowledge-base [1]. A variety of mathematical methods of determining the similarity of cases, automated adaptation of prices and validation of results are proposed in the literature [2, 7].

5. Conclusions and further research

The objective fact is that resource-based and process-oriented cost planning characteristics available in the contractors' domain provide truly explanatory models of construction cost. The effect of this planning is then converted into priced bills of quantities with unit rates presented to the construction clients. The prices do not necessarily have a relationship with actual costs of providing the item plus contractor's markup– it is distorted by the effects of social opportunity costing, subjective risk assessment, actions aimed at improving contractor's cash flows, and – specifically in the case of the Polish approach to price presentation – prorating preliminaries, overheads and profit to all prime works on the list. Thus, the bill's rates become a "black box" in terms of causality. The input from priced bills of quantities are then further processed and aggregated into the libraries of "real-life cases" to be used by construction clients and design teams. Each step of processing affects the reliability of the data. Certainly, the reliability of methods of using them in top-down estimates suffers.

The most reasonable approach would thus be to use original resource-based cost plans as the input for analyzing the costs of future schemes. With the established practices of adversarial rather than cooperative relationships between project participants, owner and design team's access to this information is limited. However, the recent switch to design-build systems, partnering, and development of Building Information Modeling [4] provide the construction industry with opportunities for better planning tools. So far, resource-based cost models are not part of comprehensive information systems. In Poland, we have a tradition of referring to resource-based analyses at all stages of cost planning and well established (though technically obsolete) data manipulation techniques, classification systems and databases. The Polish approach to using standardized resource-based cost plans, deprived of individual character, is not without certain drawbacks, which has been highlighted in the previous chapters, but we still may be one step ahead of the "old free market economy countries" in incorporating resource-based information to BIM.

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