Innovation in engineering and technological education: a judgmental application for an activity or a group of activities based on cost of model/location cost factoring

A.R.N. Molson

Independent Private Consultant/Researcher
Athens, Greece

ABSTRACT: The increasingly global nature of capital investments in facilities and of finance for future development projects has seen a concomitant rise in the requirement for construction related experts, accurate international location factor(s) cost data and developing cost models. An independent researcher gathered cost data for the construction of linear projects in the period 2007-2008, on project based financing for medium sized contractors, with an emphasis on public sector in the Greek construction industry, and analysed it. The parametric estimations are not easy learning techniques and the analysed data is limited for cost forecasting. By developing location factors, using a factoring method for an activity or, a group of activities of a project P_L, cost management professionals could contribute to a better cost management system for construction financing, design, planning, budgetary control and monitoring of project developments or, property investments, and to the institutions' initial preparation of students in the use of advanced numerical, statistical techniques and to the industrial practitioners' to test the validity of cost models.

INTRODUCTION

The role of professional engineers, valuers and estimators in a less buoyant period of economic activity must be aligned to construction industry and property market needs, hence providing better services for citizens, financial institutions and investors. The professionals should be able to manage development projects and respect legislation, the building environment and engineering technology, as well as citizens' affordability and investors' contributions [1].

Cost Estimating is crucial to construction contract tendering, providing a basis for establishing the likely cost of resource elements of the tender price for construction work. The impact of inaccurate cost estimating on contracting business is significant. An initial analysis of the factors shows that the main factors relevant to the cost estimating practice are the complexity of the project, the scale and scope of construction, market conditions, the method of construction, site constraints, the client' s financial position, buildability and location of the project. It is believed that these factors have a direct effect on productivity levels on site and performance of the construction project [2].

According to the author's case study in the Greek construction industry, an overestimated construction cost of a linear project (*owned by a public organisation*), may result in an additional contracting agreement or, to additional new prices being submitted by the subject contractor at construction stage, which could lead to a proposal budget being unacceptable to the public authority.

Molson's professional view is that:

> *The successful implementation of projects in both engineering and construction is vital, in order to maintain estimates within budgets and to achieve targets and milestones (scheduling) set up by Financial Institutions, investors and other public and private bodies. The impacts of overrun budgets and time schedules, of poor estimates and project control reports are always negative messages to the marketplace and the public. Industry must concentrate on practical improvements*.

Molson's proposal was:

> *…the development of an approach for construction cost estimations, based on location cost modelling for the Professionals and Financial Institutions, for better construction planning, budgetary control (in the valuation process) and monitoring of property investments and finance* [3].

The basic *Specification of the Proposed Cost Location Modelling* described as a process (presented in Figure 1):

…for assessing the variability and validity of each activity of a submitted estimate for a residential property fund in Greece and, simultaneously, to estimate the accepted cost (€) or factoring ratio (%) of the proposed activity, task or group of works. The variation will be compared and measured against the proposed activity cost/factor. If the tests are successful, the sum of accepted costs represents the construction cost estimation, which would be financed by the financial institutions [3].

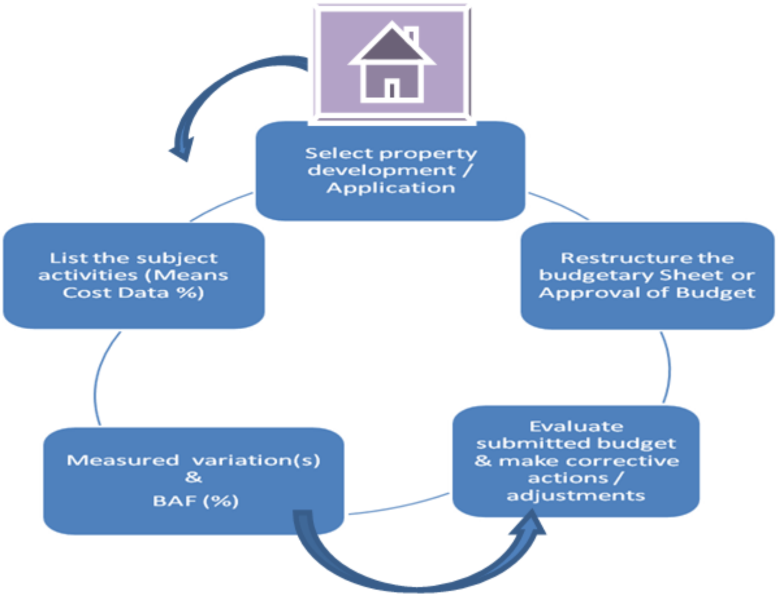

Figure 1: The proposal process model of BAF's formula.

This was briefly summarised by using the following simple *Formula* for a new residential construction (*based on submitted budget*):

Bank's Activity Factor (%) = [Proposed Budget Activity Factor a_1 (%)] x (BAF)[(Local VAT Rate)/(National VAT Rate)] x [(Local Material Inflation)/(Athens' Material Inflation)] + |V1| =>
=> Bank's Activity Factor (%) = [a] + |V1|,

where:

i. [a] is the outcome of factoring calculations, which is presented as: [a] = (a_1 %) x BAF's Parametrical Factor
ii. V1 is the variance : |V1| = [(BAF) – (a)] and
iii. BAF is the abbreviations of *Bank's Activity Factor*.

Note: [BAF's Parametrical Factor] = (BAF)[(Local VAT Rate)/(National VAT Rate)] x [(Local Material Inflation)/(Athens' Material Inflation)], which is a summarised parameter (%) that could be calculated and then incorporated into the subject *Formula* as a figure from an equation estimating system created by the range of VAT (ranges are : 19% - 21% - 23% or 13% - 15%, based on the Financial period of application) and the Material's Inflation Ratio. Thus, the development a Material's Inflation Index for various Locations $|L_s|$ is required in practice.

For example, to estimate the accepted/approved cost location factor of a task for *excavation, foundation and structural concrete frames* (type = residential property), located in the border zone (e.g. Leros Island), all parameters are input into the Bank's Activity Formula for year [*y*] 2010, as shown below:

Code 1.0 [Activity: Excavations, foundation and structural concrete frames]

Bank's Activity Formula (*y* = 2010), as shown below:

$$[22.60\,\%] = [24.0\,\%] \times [(15\%)/(23\%)] \times [(110)/(100)] \Rightarrow [22.60\,\%] = 17.2174\% + |V1| \Rightarrow$$
$$\Rightarrow [22.60\%] = [17.2174\,\%] + [5.3826\,\%] \Rightarrow 0.0$$

Where: (22.60%) is the subject factor for Leros Island; (24.0 %) is the proposed factor for the subject task with *Code 1.0*; (15%) is the local VAT (2010) for Leros region and (23%) is the national VAT (2010); (110) is the local Material Cost Index; (100) is the Athens's Material Cost Index.

There is a variance of 5.3826 % *|V1|* for the subject activity with *Code 1.0*, based on Means Cost Data. These findings could provide a quantitative support for initial hypothesis testing in Statistical Applications.

PARAMETRIC ESTIMATING

Parametric models (e.g. shopping models, models in systems biology) relate dependent variables to one or more independent variables based on statistical relationships to provide an estimate of the dependent variable with regards to previous data [4].

Parametric estimating is a technique that develops cost estimates based upon the examination and validation of the relationships, which exist between a project's technical, programmatic and cost characteristics, as well as the resources consumed during its development, manufacture, maintenance and/or modification. Parametric models can be classified as simple or complex. Simple models are cost estimating relationships (CERs) consisting of one cost driver. Complex models, on the other hand, are models consisting of multiple CERs, or algorithms [5]; (*signal engineering e.g. Robbins-Monro stochastic approximation (RMSA); algorithm for gradient-descent optimisation algorithm; AML algorithm*), to derive cost estimates.

The benefits of using parametrics are well documented. It is estimated that the savings to proposal preparation is between 40 percent and 80 percent as compared to the *normal* bottom-up approach. Parametric tools and techniques have much more versatility than other estimating approaches. There are numerous reasons for this, and there are a few:

- better estimates are provided, often in a matter of minutes;
- there exists a high-quality link between the technical and cost proposals;
- the data are well understood through calibration and validation activities;
- it is much easier to estimate conceptual designs;
- early costing cannot be done effectively in any other way;
- no bill of material (BOM) is required;
- it is much easier to handle scope, technical, and performance changes [5]. (Source: *International Society of Parametric Estimating Handbook*, Fourth Edition, April 2008).

Parametric estimating, which involves using design parameters to estimate cost and schedule for hardware, software, and microcircuits is very popular today with both government and industrial agencies throughout the world. It has grown extensively since its origins in the 1970s, and is often used as the sole or primary estimating method in many organisations. Despite its popularity, however, parametric estimating presents numerous challenges, and can produce adverse effects if misused [6].

PARAMETRIC ESTIMATING TODAY

New models and techniques are being developed, existing models such as the PRICE-H, -S models are frequently being enhanced, and some groups are dedicated to ongoing research in selected areas. For example, the International Function Points Users Group (IFPUG), the Parametric Cost Estimating Initiative (PCEI), Cost As An independent variable (CAIV) [6], Constructive Cost Model (COCOMO), e.g. COCOMO-81 Web tool, Constructive Quality Model (COQUALMO), Software Testing Reliability Early Warning (STREW), and others, including the International Society of Parametric Analysts (www.ispa-cost.org) [5].

There are numerous parametric models (e.g. supervised latent Dirichlet allocation (sLDA), simple OLS model) *and* (new) *methods* (e.g. Estimating S-system Parameters, the output error method, the Lenberg-Marquardt method), available for divers applications:

> *…There is a challenge, however, in that parametric models and methods must be properly used to be effective. A user must understand the models he and she is using and be trained and experienced with them. Users must also perform calibration and validation of models and collect quality, relevant historical data. Users must also understand the current limitations of software parametric estimating models and act accordingly. If models and methods are used improperly, parametric estimating will be of little or no value* [6].

From the initial literature review, two parametric estimation approaches were initially investigated in flood control design (hydrology) [7], the Classical and Bayesian …*The Bayesian analysis is a methodology which enables the combination of information sources as well as allows the explicit evaluation of the effect of all sources of uncertainty upon the decision variables* …and new approaches such as in Reference [8]. The New Keynesian Phillips Curve (NKPC), either for measuring banking efficiency with econometric techniques or linear programming tools [9].

THE INDUSTRIAL SURVEY

Data Gathering and Research Methodology

The population used in this study includes professionals, who submitted project progress reports based on bill of quantities and published (www.ggde.gr) national cost indices (codes) for approved construction budgets (*signed* *contracts: Design & Build or Construction widely known as 1st, 2nd, 3rd or 4th Α.Π.Ε., 1st, 2nd Σ.Σ.Ε., 1st, 2nd, 3rd or 4th Π.Κ.Τ.Μ.Ν.Ε.*, etc) to the Greek public authorities (e.g. *Technical Division of Municipality*, other), at construction phase, in order to provide the necessary project control data (*estimated the sum of workbook budgetary sheets*) and prediction of final budget figure requested by the Conditions of Contract (*namely, based on National and European Union Legislation*).

The submitted actual budgets were gathered from the Greek Contractors registered within the Greek Professionals and Firms Control Systems (widely known as M.E.E.K., M.E.K., etc, see: www.ggde.gr, www.pedmede.gr), incorporating the Technical Councils' expert opinions, the approved amendments and design modifications, other. In practice, each contract is networking and the cost codes are recorded. The subject reports exclude *time* data and the target date is *Project Completion*.

Before developing the questionnaire, a process model was developed and an industrial survey of the Greek Construction Firms in the period from 4th quarter 2007 to 4th quarter 2008 using structured questionnaires (completed after the approval of project report) and semi-structured interviews on sites [10]. The sampling of submitted project progress reports (budgetary information) comprises 54 submitted cases for approval at the construction stage of Contractor's Contracting Obligation (see Table 1).

Table 1: Sampling of submitted project progress reports by geographical distribution - Year 2008.

Geographical Area	Submitted Budgets Applications - Project Progress Control		Construction of Linear Projects [a],[b],[e] Ind. Plant and Building Construction [c],[d]	
A/A of Province (Regions) [http://www.ypes.gr/el/Regions/]	Construction Project Reports (94.44%) @51 cases	Design & Build Project Reports (5.56%) @3 cases	Water, Wasted & Drain Systems [a] (77.78%) Geo-thermal Heating Systems [b] (3.70%) Building [c] (5.56%) Waste Treatment Plant [d] (7.41%)	Roads [e] (5.56%)
Attica incl. Piraeus	3	-	-	3e
South Aegean	4	1	4a, 1d	-
Central Macedonia	11	1	8a, 3c, 1d	-
Crete	9	1	9a, 1d	-
North Aeagean	9	-	9a	-
West Macedonia	5	-	3a, 2b	-
Sterea Ellada	1	-	1d	-
East Macedonia & Trace	1	-	1a	-
Peloponnisos	6	-	6a	-
Thessalia	1	-	1a	-
West Helladas	1	-	1a	-

Due to size, only the basic data analysis, the issue of proposed specification and an example are given for the cost estimations based on a location cost model for construction of a linear project P_L, which emerged from the survey. More specific outcomes of the survey are given in the following points (*54 reports with value > 1,0 million Euro*):

- Many participants (74%) agreed that parametric cost estimations are not easy learning techniques.
- Many participants (74%) agreed that the project control reports submitted for evaluation were drawn based on the conditions of contract and the construction laws (National and European Legislation).
- Many participants operate a cost estimating system (79.63%), e.g. Ergoland, Logicial Procost, etc, while (20.27%) apply simple cost control systems for reporting mounted on spreadsheets (simple or sophisticated platforms).
- Many assessors (62.96%) agreed that a cost location factoring model mounted on spreadsheets can improve construction cost estimations at the feasibility and design stages and also for performance measurement after the completion of project.
- Many participants (79.63%) agreed that the proposal cost location model should be initially used for groups of activities/tasks such as hydraulic systems, pump stations, water tanks, ground works excavations, etc.
- Many (55.55%) participants agreed that the proposal process model could be used as a simple model for validation of proposal budgets and it could contribute to a better cost management system.
- Few (9.26%) contractors submitted a claim for an additional contract (e.g. Σ.Σ.Ε.).

Specification of the Proposed Cost Location Model covers construction process from *Construction* phase based on a signed construction contract and as a close loop Feed-forward control approach to support the stage of feasibility studies. Thus, the construction cost assessor/consultant can use a simple location cost model to check the variability and validity of a submitted project progress report by the subject contractor and also the proposal budget of a similar type of project, under the development approach/feasibility studies and design phases. A location cost factor can be developed from in-house data or, from the historical cost information of previous projects.

Example for an Activity or Group of Activities/Tasks for Construction of a Linear Project

In order to estimate the accepted/approved cost location factor of *Group of Activities/tasks @Hydraulics*, (type=linear programming project), located in the Peloponnesus Province (e.g. town's infrastructure development programme), all parameters are input into the Project's P_L Activity Formula for year [*y*] *2010*, as shown below:

e.g. Linear Infrastructure Project: *Construction of drain and waste systems for the neighbourhood* Saint George and the New Factor $_{y=2010}$ is calculated …for the similar project …in Pelo/sos Province.

Code 3.0 [*Group of Activities/tasks @ Hydraulics*]

Project P_L Activity Formula (y = 2010) is calculated as shown below:

[New Factor $_{y=2010}$] = [H_{data} Factor@Hydraulics] x $\mathbf{P_L}$AF [Local VAT Rate)/(National VAT Rate)] x [(H_{data}Group@sum)/(Approved Budget of Subject Group of Activities/Tasks)] $\Rightarrow$
[New Factor $_{y=2010}$] = [1.0] x [(23%)/(23%)] x [(100,000 €)/(120,000 €)] $\Rightarrow$
$\Rightarrow$ [New Factor $_{y=2010}$] = *0.0833, which is rounded up 0.83*

Where:

Rate 1.0 is the old factor for Northern Pelo/sos;
Ratio (23%) is the local applied & national VAT (2010);
Sum (120,000 €) is the sum of all activities under the task @Hydraulics and
Sum (100,000 €) is the sum of the subject location (official budget).

The above presented example may be an easy way to introduce a location cost model as a part of the *construction cost estimations* issue to undergraduate engineers.

CONCLUSIONS

The increasingly global nature of capital investments in facilities and of finance for future development projects has seen a concomitant rise in the requirement for construction-related experts, accurate international location factor(s) cost data and developing cost models/location cost factoring.

By developing location factors using a factoring method for an activity or a group of activities/tasks for the construction of a linear infrastructure project, professionals with international and regional cost estimating or quantity surveying experience could contribute to a better cost management system for construction financing, design, planning, budgetary control and monitoring of project developments or property investments, and to the higher engineering and technological education institutions' initial preparation of students - graduates in the use of advanced numerical, statistical and forecasting techniques and further research, and finally, to the industrial practitioners' to test the validity of cost models.

REFERENCES

1. Molson, A.R.N., Expanding the integration of technological education and industry through research into developed cost forecasting and control strategies for contractors with the incorporation of econometric models. *World Transactions on Engng. and Technol. Educ*., 6, **1**, 139-142 (2007).
2. Akintoye, A., Analysis of factors influencing project cost estimating practice. *Construction Management and Economics*, 18, 77-89 (2000).
3. Molson, A.R.N., Expanding the integration of engineering and technology education and financial institutions with the incorporation of location cost modelling in construction cost estimations. *Proc. 1st World Conf. on Technol. and Engng. Educ.*, Kraków, Poland, 14-17 (2010).
4. Sherriff, M. and Williams, L., A Method for verification and validation certificate management in eclipse. *Proc. 2005 Automated Software Engineering Workshop on Software Certificate Management (SoftCeMent'05)*, Long Beach, California, USA, 19-22 (2005).
5. International Society of Parametric Analysts, *Parametric Estimating Handbook*. On-line Handbook, http://www.ispacost.org/PEIWeb/Third_edition/newbook.htm
6. Ferens, D.V., Parametric estimating - past, present, and future, air force research laboratory. Information Directorate Wright Research Site Keynote Address for the *9th PRICE European Symposium*, 20 October (1999).
7. Wood, E.F., Flood control design with limited data: a comparison of the classical and Bayesian approaches. Design of water resources projects with inadequate data. *Proc. Madrid Symposium, UNESCO Publication Chapter*, 1, 469-

483 (1974) and also *Proc. Symposium on the Design of Water Resources Projects with Inadequate Data*, Madrid, Spain (1973).
8. Gabriel, V.J. and Martins, L.F., The cost channel reconsidered: a comment using an identification-robust approach. Discussion Paper in Economics, University of Surrey, 4-13 (2010).
9. Weill, L., Measuring cost efficiency in European banking: a comparison of frontier techniques. *J. of Productivity Analysis*, 21, **2**, 133-152 (2004).
10. Dawood, N. and Molson, A., Development of a cost forecast and control strategy for the Greek construction industry. ARCOM - Association of Researchers in Construction Management. *Proc. 12th Annual Conf. and Annual General Meeting*, 11-13 September, 1, 566-575 (1996).