COST ANALYSIS AND FORMULATION OF COST MODELS FOR TWO-STOREY BUILDINGS CONSTRUCTION IN MALAYSIA

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Abstract: This paper will describe the ongoing research work which is aimed at producing a cost forecasting and planning model most representative of the building in Malaysia. Due to the limitation of data and time, the model is targeted for a particular type of building. Its techniques can however be expanded to other types of buildings. Data was collected from the two-storey residential building projects. Through the use of elemental cost analyses data, the interrelationships of building costs were simulated using the Monte Carlo techniques. The results obtained can form the basic guidelines in cost forecasting, planning, balancing, comparison and controlling of similar future projects.

Keywords: Cost Modelling, Elemental Cost Analysis, Cost Planning, Cost Forecasting, Cost Control, Monte Carlo Simulation.

1.0 INTRODUCTION

The building industry is undoubtedly one of the most important sector of the Malaysian economy. A substantial percentage (Bank Negara Malaysia) of the national gross domestic products emanates from this industry. A sound management in this sector will have great impact on the economy of the country as it involves a huge workforce, suppliers of building materials, manufacturers, and other professionals. The most important component of sound management is none other than cost efficiency. To achieve cost efficiency, there must be a well-established system that developers or their clients can rely upon to make their investment decisions. Once a decision has been made for a project to be implemented, it is critical for the implementers to have a good system of control and to keep the cost of the building to within the approved budget. The way to achieve this is basically to have accurate cost forecasting (pre tender) and cost planning model.

Cost forecasting allows the determination of preliminary estimates of a building before detail design and building particulars are prepared. This will be an important factor to consider in the client's overall strategy for an investment. Hence, accuracy of estimates is a pre requisite to a good investment decision.

Cost planning enables the control of project cost to within a predetermined sum at the outset of the project implementation. The information needed for planning are obtained from the cost study and cost analysis of past projects. Cost study refers to the breaking down of the total cost of building to establish its relationship whilst cost analysis is the systematic breakdown of cost data, usually in the form of elements. By analysing and collating these data, a cost model can then be formulated.

The main aims of this research are to conduct an extensive cost study for the formulation of a cost forecasting model (approximate estimating) and elemental cost analyses (cost planning) for double storey construction in Malaysia. The model is not restricted to only double storey buildings but can be used in any other buildings that have past data recorded in a similar format.

Although extensive research has been carried out especially in U.K (Brandon), the outcomes of the research are not so applicable to Malaysia because of different building requirements, productivity, climate design, labour cost, location, resources availability, construction techniques and many other factors. It is hoped that at the conclusion of this research, the following objectives can be achieved: -

- Cost Modelling using data from elemental cost analyses. Simulated data using Monte Carlo techniques will be compared using various methods of averaging to determine its accuracy.
- Comparison of the accuracy of cost forecasting models using traditional techniques of cube method, superficial area method, storey enclosure method and elemental method.
- Determination of sensitivity and cost significance of each element towards total building cost.

- Formulation of a cost model based on regression analysis.
- Identification of cost distribution of each functional element towards the total cost of a building.
- The spin-off from cost analyses such as comparison cost variation against tender price index and cost index, the influence of project size to cost of construction, the fluctuation of cost under different economic environment.

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2.0 COST MODELLING

Cost modelling may be defined as a systematic representation of a procedure that delivers adequately acceptable output for an established series of input data. The procedure is determined through extensive analysis of data of a building that has influence on its cost and after being satisfied with the ability of the procedure to give a good representation of costs. The main aim of cost models is to simulate a current or future scenario in such a way that decision makers can made use of the results to decide their investment decision and the designers can optimise their design as well as cost planning and cost control.

Raftery (1987) described how the development of cost modelling has taken place in U.K since 1950. The first systematic approach to building cost modelling can be attributed to Building Cost Information System (BCIS) introduced by the Royal Institute of Chartered Surveyors in late 1950. Since then the development of cost model has gone through a number of stages. The first stage saw the introduction of elemental analysis technique in the development of a cost model when the Royal Institute of Chartered Surveyors, UK, adopted a standard form of cost analysis. The second stage revolved around the extensive use of regression analysis. Kouskoulas & Koehn (1974), using six independent variables, presented an example of this model. Beeston (1987) and Skitmore (1987), were dissatisfied with the accuracy of regression model in predicting costs. The subsequent stage saw the introduction of the stochastic or probability approach which takes into account the uncertainties and imprecision of factors affecting estimates. This approach is often based on the Monte Carlo techniques. Touran (1993) highlighted some difficulties in using this approach and suggested the incorporation of subjective correlation into the model based on the experience of an estimator. Current approaches towards cost modelling emphasise the exploration of artificial intelligence and knowledge-based database system. Heng Li (1996), on the other hand, explores the use of artificial neural network in cost estimation.

The Monte Carlo technique is a method, which can be used to simulate the cost of a component/ element many times. During each stage of the process, the computer selects at random a cost from an input distribution for that component. The input distribution represents the estimators' perception of the feasible range of cost for that component. It is usually based on historical data. The output from this evaluation is usually given in the form of frequency curves and cumulative probability diagrams. Thus, it is usually possible to specify a given degree of risk and read off an appropriate cost from the curve.

All estimating techniques can be described as models. The technique adopted is based on the purpose and usage of such models. Building cost models meant for design optimisation, cost comparison and cost balancing commonly use input data from elemental analyses. Models for approximate estimating cater mostly for the purpose of forecasting construction cost to determine the feasibility of a project at the preliminary stage and to check against tender price. In addition, it can also be used to indicate the relative costs of different design and the financial yardstick to alternative construction methods, finishes and services installation.

3.0 COST ANALYSIS AND INDICES

Cost analysis can be defined as 'the systematic breakdown of cost data to facilitate examination and comparison'. The Institution of Surveyors, Malaysia (1988) has introduced a Standard Form of Cost Analysis which provides standardisation of elements of building in Malaysia. The format is basically adopted from The Royal Institution of Chartered Surveyors Building Cost Information Service, U.K with slight modification to suit local environment.

A cost index is mainly use for adjustment of cost data due to the varying dates of implementation. It can be used to adjust historical cost data to a particular time reference for comparison purposes and to predict and assess future trends in price levels. The two main indices currently available in Malaysia that are applicable for the building industry are Building Material Cost Index (BMCI) and Tender Price Index (TPI). The BMCI was introduced by the Department of Statistical, Malaysia (1999) and is a special purpose index, which is based on the Laspeyres formula. It is designed to measure the average rate of change in prices of selected building materials utilised in eight categories of building in Malaysia. The index is published monthly, with 1991 as the base year. The TPI was introduced by the Department of Public Works (1998) to monitor the trend and variation of tender prices for projects implemented by the Department. The index is computed based on the information of cost per square metre for projects handled by the Department. It is published twice annually. The main advantage of TPI is that it takes the tendering market into account.

4.0 CONCEPT AND METHODOLOGY

The estimating techniques that will be thoroughly tested are those with single prices, regression analysis and Monte Carlo techniques. For the single price model, the approaches that will be used are the cube method, the superficial area and the storey enclosure method. These techniques traditionally produced the least accurate prediction but because of their simplicity, they are more useful at the early stages of the projects' inception and for budgeting purposes.

The regression analysis technique will be used to find a formula or mathematical model, which best describes the relationship of data collected. For this research, independent variables that may be considered are built-up area, storey height, land size, specification level and project size.

The Monte Carlo simulation techniques, a well-established method, will be used to solve problems especially those associated with uncertainties. Since the construction activities are full of uncertainties, the use of these techniques is most appropriate. For this research, simulation using randomly generated numbers will be applied to the probability distribution of each element generated from the historical data. From this multiple runs, it is possible to generate a probability profile for that particular element which can give statistically confidence statements of the cost.

The historical data are obtained from Contract Documents of past projects implemented by the private sector. The cost data are extracted from the Bill of Quantity and are grouped into functional elements as introduced by the ISM. The data are grouped into six main categories; namely, the Substructure (two elements), the Superstructure (eight elements), the Internal Finishes (three elements), Fittings and Furnishings, Services (eleven elements) and External Works (five elements). Due to the characteristics of double storey buildings and the inconsistencies in implementation, certain elemental rate could not be obtained and are left out in the analysis. For example, piling works differ vastly from one project to another. Some of them prefer to incorporate it into a single contract with substructure and superstructure works while others either call for a separate contract or use a client-preferred contractor based on a negotiated price. Other elements that are also excluded from the analyses are refuse disposal, air conditioning and etc. which are uncommon in double storey building.

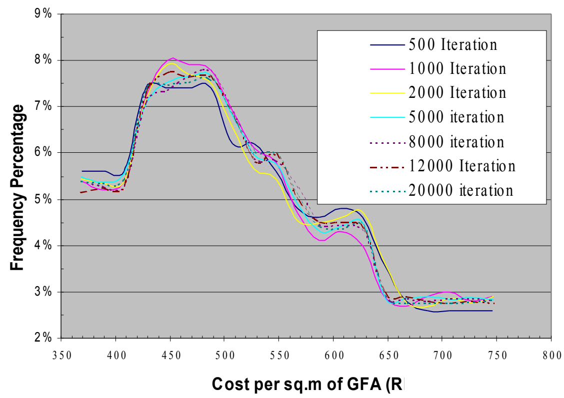
The data obtained through the analysis will be updated using TPI to December 1999 as the reference point of comparison. Although the index is derived from public works, it is not expected to have much difference and should give a good representation of the private sector as well. As at the time of writing this paper, only six sets of data have been obtained. The results and analysis will be based on these sets of data. It should give some preliminary indication of the possible future outcome when more data became available.

5.0 RESULTS AND ANALYSIS

Due to space and time constraints, only limited analyses are presented here. However the analysis carried out should be adequate to provide some early indication of the applicability of various techniques in formulating cost forecasting and planning model. The results and analysis presented here should be treated as a preliminary indication of probable final outcomes only, as the number of samples (six) is too small to make any conclusive statements.

The first analysis carried out was to determine the stability of the Monte Carlo simulation techniques. This was done by simulating random data from the frequency curve (total cost) of historical data for 500, 1000, 2000, 5000, 8000, 12,000 and 20,000 times. The simulated frequency curves for each of this range

Fig.1 Frequency Curve with varying interatic simulation

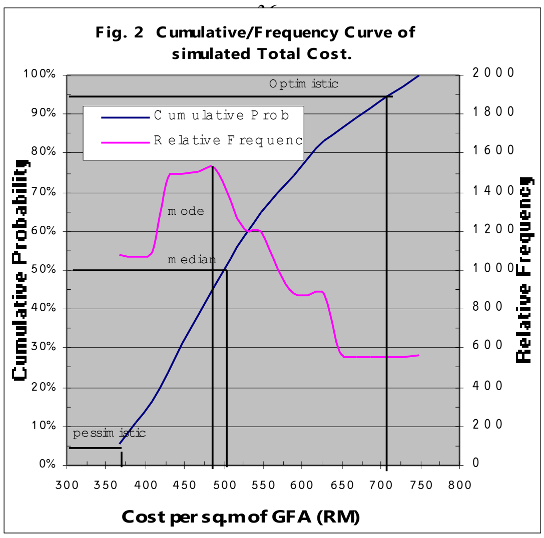


of simulations were then compared. The results, as illustrated in Figure 1, shows that the frequency curves obtained for 8,000, 12,000 and 20,000 were quite close to each other. Hence it can be concluded that the model need at least 8,000 times of simulation before it stabilises. In any event, for all analysis presented in this paper, it should be noted that it was based on 20,000 times of simulation.

The second analysis carried out was mainly to determine the accuracy of the cost forecasting model. Figure 2 shows the results of the analysis, i.e. the relationship of total cost per square metre of gross floor area (GFA) versus cumulative probability and relative frequency. The frequency curve seemed to skew to the right (positive skewness) and multimodal. The total cost is made up from the summation of fifteen (15) separate functional elements. At 5% and 95% confidence limit, one can deduce that the costs per sq.m of GFA are RM367.00 and RM712.00 respectively. Hence a cost adviser can confidently tell an investor that for a building of 123.95 sq.m, the forecasted cost of each unit shall be a minimum of RM 44,489 and a maximum of RM88,252 (712 * 123.95). To derive the most representative average value from the frequency distribution, various statistical analyses were carried out. They were the weighted mean, arithmetic mean, mode and median. The weighted mean is based on the popular formula of PERT in estimating time duration. This method was adopted because a past study by Ng [1996] yielded some good results. It was calculated by adding the pessimistic, optimistic and 4 times the mode value. The sum of it was then divided by six. The pessimistic and optimistic value was taken as 5% and 95% of the frequency curve respectively while the mode was the value with the highest frequency.

To compare the accuracy of these techniques in cost forecasting, each of this simulated value was compared to an actual value obtained from a most recent project. The results of this analysis are as shown in Table 1. The outcomes indicated that cost predicted using the value of median of the simulated distribution (based on 20,000 of simulated data) seemed to yield the most accurate results compared to other techniques. The weighted and arithmetic mean methods seemed to overestimate the project cost while the mode and median method underestimated it.

Table 1. Accuracy of Cost Forecasting Model



Averaging Method	Simulated Cost (RM) Per sq.m of GFA	Simulated Total Cost (RM)	% Different compared to Actual T.Cost
Pessimistic(p)			
Mode(m)	*488.00*		
Optimistic(o)	*712.20*		
Weighted Mean*	518.50	64,268.00	1.30%
Arithmetic Mean	525.40	65,123.00	2.60%
Mode	488.00	60,488.00	-4.70%
Median	508.00	62,967.00	-0.80%

* Weighted Mean = (p+4*m+o)/6

Actual Gross Floor Area(Sq.m) =123.95

Actual Cost per Sq.m of GFA(RM) =512.00

Actual Total Project Cost (RM) =63,464.00

The above analysis only focuses on the total cost of the building as a whole and is meant for cost forecasting. However for the cost planning model, a more detailed analysis needs to be carried out. Each of the elements that make up the total cost needs to be analysed separately. The methodology used is similar to the cost forecasting techniques with the exception that the averaging technique was applied to all elements rather than just on total cost. The values of weighted mean, mean, mode and median from each element frequency distribution were individually calculated. Each of this value was then multiplied with the gross floor area to obtain the cost per element.

Table 2. Accuracy of cost planning model

Ref	Element	Simulated Cost				%
		Wt. Mean	Mean	Mode	Median	
1	Substructure	6,284	7,201	5,784	6,802	11%
2A	Frame	5,825	5,476	6,071	5,577	9%
2B	Upper floor	3,672	4,026	3,146	3,654	6%
2C	Roof	4,985	1,973	3,818	7,708	13%

2D	Stair	1,657	1,973	1,458	1,817	3%
2E	External walls	2,261	2,183	2,299	2,206	4%
2F	Windows and External Doors	4,536	4,675	4,330	4,395	7%
2G	Internal Walls & Partitions	3,697	4,781	3,036	4,467	7%
2H	Internal Doors	1,818	2,030	1,623	1,865	3%
3A	Wall finishes	5,258	6,063	5,040	6,054	10%
3B	Floor finishes	5,825	6,376	5,319	5,945	10%
3C	Ceiling finishes	2,604	2,498	2,655	2,480	4%
5A	Sanitary Appliances	2,481	2,930	2,236	2,734	5%
5B	Plumbing Installation	3,291	3,462	2,995	2,995	5%
5E	Electrical Installation	2,023	1,974	2,056	1,989	3%
	Total cost	**56,215**	**57,621**	**51,864**	**60,690**	**100%**
	Actual cost t =	RM63,464				
	% Difference	11.4%	9.2%	18.3%	**4.4%**	

The cost of each element was then added to form the total cost of the project which could then be compared with actual total cost to determine its accuracy. The results are tabulated in Table 2. It is interesting to note that the cost planning model also seems to favour methods using median values. The accuracy obtained is within 5% of the actual cost. With this confirmation, cost planning based on the individual elemental rate using median values can be adopted for the planning of future design works.

The data obtained above can be slightly modified to be used as cost comparison and balancing for other housing construction. For instance, from Table 2, it can be concluded that on the average, 11 % of the total cost of a building is spent on sub-structure works, 13% for roof structure and etc. For overall cost distribution, refer to Chart 1.

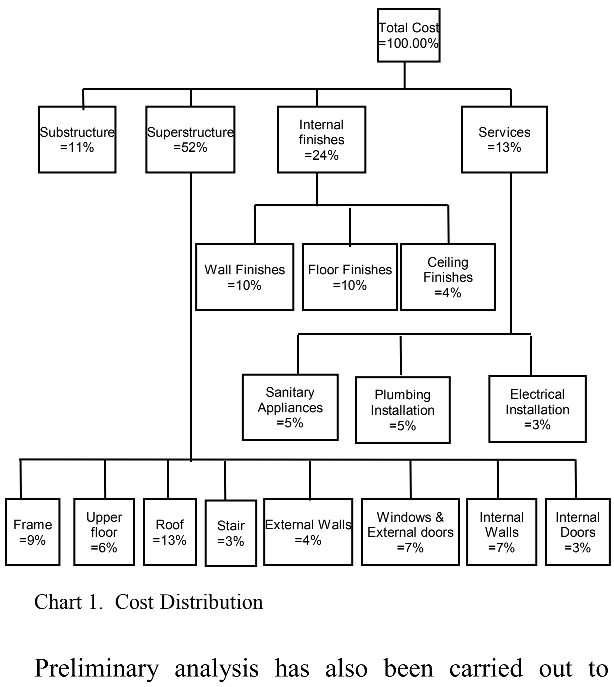


Chart 1. Cost Distribution

Preliminary analysis has also been carried out to determine the relationship of the number of houses with construction cost. No clear relationship could be established for now partly due to the limited size of the database. Nonetheless, the initial analysis indicates that the relationship is not linear.

6.0 CONCLUSIONS

The main advantage of using the cost forecasting technique above is the speed of obtaining estimate. However the difficulty is in the selection of the appropriate rate to be applied. A ready access of current cost information together with knowledge of future trends is vital to achieve reliable results. The analysis of cost using past building projects in elemental format provides us the best guide for cost planning of future projects with optimum economic efficiency. Cost studies are therefore an important aspect of the design of buildings. The performance of the models appears to be satisfactory at this preliminary stage as the simulated results are within the acceptable range of accuracy.

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