

# **COST MODELLING FOR STANDARDISED DESIGN PROJECTS**

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In 1992, the Egyptian government launched the national project for building 1500 schools every year. Over the period 1993-2005 more than 15000 schools have been built and still there is an on going demand due to the demographic factors besides the political inclination to erode illiteracy as a proactive national security measure. The share of school buildings in the national budget is increasing. Over the last three five-year plans, the total expenditure on school projects exceeded 13bn Egyptian Pounds. This paper aims at develop a price-forecasting model for school buildings in Egypt in an attempt to optimise the deployment of the scarce resources of the developing country. The model developed based on data collected in Egypt for actual prices of 120 schools built over the period 1994-2005 to predict the cost of school projects in the initial stage using ordinary least squares (OLS) regression. The study benefits of the unique attribute of this national project that implements standardized design hence reducing the number of product variables and providing further in-depth analysis of the effect of other variables. The developed model besides being simple and may be easily comprehended by practitioners in Egypt, when tested, reflected high accuracy.

Keywords: cost modelling, LDC, mark-up, standardised design.

## **INTRODUCTION**

Construction cost estimating and modelling is a very rich area that attracted the attention of many researchers due to the vital role the construction industry plays in any economy. Yet it still seems fragmented to the extent that calls for further work either to address some of the existing gaps or to improve previously established techniques.

According to Akintoye and Fitzgerald (2000), the main method still being used by companies is the standard estimating procedure, which is found in most estimating textbooks, where the costs of construction (labour, material, plant, subcontractors) are established and to which an allowance for overhead and profit is added. The estimate is prepared in a logical manner based on information of historical costs. However, this method of estimating has been criticized for its wide variability (Beeston1986) as reflection on the gap between research and practice.

This study aims to investigate cost estimating in construction projects in relation to the current practice in Less Developed Countries (LDC). Since 1992, the Egyptian Government has launched a national project to build 1500 schools every year. The General Authority of Educational Buildings (GAEB) was assigned this task. The Egyptian national project of educational buildings has been identified as the case study for this research due to its unique attributes featured in the standard sets of designs (templates) applied to the three stages: primary; preparatory and secondary.

Hence, the novelty of this study is the investigation of cost modelling for standardised design projects based on a unique data set stretched over 12 years. During the period 1992-2003 GAEB built a total of 13350 schools contributing to more than one third the total number of schools in Egypt; 36332 schools with about 15 million students (out of which %47 are girls) equating to about 21% of the whole population.

GAEB produces tender documents for every school, and then invites bidders. The tendering process is conducted in two main fashions: general public tenders or short lists of technically pre-qualified contractors. In either case contractors are provided, over and above the set of drawings and specifications with a priced bill of quantities where an estimated price for every item is set by GAEB cost estimators. The latter review their estimates on yearly basis with regard to inputs' price movement in the market and issue a general comprehensive price list that embraces any item that might be required for the few templates used.

GAEB cost estimating activity is based on the market prices of inputs. This practice is similar to the prevailing trend among most practitioners. Despite the declared strategy of GAEB that estimates include at least 15% profit margin for contractors, still bidders ask for a considerable mark up ranging from 10% up to 40% due to different reasons that will be discussed later in the following sections of this study. So far, this has been the case for over 12 years. GAEB has been updating its price list every one or two years but could not eliminate the mark up requested by bidders who are happy with 15% profit margin yet assure that GAEB price lists do not provide such margin. The mark up varies from one price list to another though. Thus, we may reasonably assume that the mark up acts as an adjustment tool due to the perceived inaccuracy of the estimates of GAEB prices by bidders. Consequently, for GAEB, the actual costs considerably exceeded the budgeted costs. Surprisingly, this variation despite non-constant has been prevalent for the past 12 years. In LDC with scarce resources, such variation may lead to delaying final payments until the consequent additional funds required are deployed by the already overburdened Governments. Contractors, especially those who are financed through loans with interest rates soaring up to 15%-18% may suffer lethal consequences.

GAEB like most practitioners has been following the same process in cost estimating over years. Such process can be assumed to be fairly consistent as is the case with the majority of public sector departments. The only changes occur to the value of the inputs (i.e. the prices of material, labour and equipment being the main cost items) as prices change over time. However, this process seems inaccurate as featured in the recurrent request for mark up by bidders. Still the variation in the level of mark up remains ambiguous. In the sections to follow, the study will investigate this variation in an attempt to develop an estimating cost model with an acceptable level of accuracy.

## **RESEARCH METHODOLOGY**

This study comprises of a literature review followed by data analysis, model building then testing and concludes by some recommendations for further development. The literature review section will critically review two main topics: standardised designs and construction cost estimating and modelling.

This study aims to investigate three main issues:

- The advantages of standardisation of design based on the case study in hand.

- The prevalent inclination towards the simple single unit estimate amongst practitioners through an extensive review of the cost modelling literature.
- The utilisation of standardisation in building a simple cost model easily understood therefore hopefully will be adapted by practitioners.

## **LITERATURE REVIEW**

### **Standardised design**

Hooper (1998) investigated the concept of standardisation in the house building industry in the UK. According to Hooper:

“The development of standardised house types facilitates standardisation in the technology of construction, and is one of the key means whereby large house building firms can gain advantages of economies of scale in production.”

Hooper stated that the main advantages conferred by standard house types relate to:

- Facilitating the process of accurate site appraisal for land acquisition;
- Monitoring and minimising construction costs;
- Responding to the extreme volatility in the housing market.

Hooper concluded that most of the observed process of standardisation was a rational response to conditions of uncertainty and significant levels of risk in a highly volatile market.

The concept of standard design has been applied to large-scale construction projects in Egypt in housing, education and health since mid 80s. The main advantages of adapting a standard design to school buildings were:

Reduced costs having eliminated the need for professional designers and consultants for every project. Instead, they were substituted by full time staff engineers who provided both cost efficiency and better control.

The supply chain in general and contractors in particular usually conducting several projects concurrently reaped the benefits of synergy and the economies of scale, featured in centralised functions, higher efficiencies, more control and consequently reduced costs. Repetitive work enhanced efficiency as staff moved up on the learning curve. Comparatively, contributed to more accurate estimates when setting budgets and forecasting annual needs. Yet the accuracy of the estimating process as whole will be discussed further.

A flexible system adapting an “off the shelf” notion whenever a design is required for a new project. Eliminating the design phase reduced time and contributed to remarkably high levels of output. GAEB could have hardly managed to build 1500 school every year if this system was not adapted.

Provided GAEB with an unprecedented opportunity to standardise the technical specifications for the requested material. Hence, acting as an important and effective client in the construction material market due to the scale of work.

Moreover, GAEB exploited this favourable position to have a firmer grip on the supply chain with regard to the quality control of the construction material. Overall, GAEB managed quality quite effectively adapting a proactive approach through the collaborative relationship with the upstream levels within the supply chain.

### **Building Economics and Cost Modelling**

Cost estimating had developed through gradual stages but had been related to quantity surveyors for a considerable period. The evolution of research addressing the accuracy of this approach drew the attention to the need for further research to improve the accuracy of estimates. Researchers then embarked on investigating all the factors and variables affecting cost in more detail introducing new techniques and in some cases getting too much involved in niches that albeit enrich the research and add to the knowledge, its applicability to the real world of practitioners is to be questioned.

Despite the rigorous research over the past thirty years addressing the area of cost estimating from different angles and view points, still in many parts of the world the simple technique used by the quantity surveyors seems to be prevalent. A shift from a traditional trend to a new trend is a change that needs a solid foundation of change management system. According to Turin (1975), management is the scarcest of all resources. Turin was addressing the construction case in the UK so comparatively management is indeed a crucial problem in developing countries especially Egypt. The fallacy of rationality in the construction world or as Turin (1975) calls it a world of “as if”, as if all stakeholders know what is best for them bearing in mind the different agendas.

The dynamic environment and the economic turbulence Egypt has experienced for over two decades so far caused a remarkable shrink in investments by all stakeholders in the construction industry. A general trend of short term planning superimposed any prosperous long-term plans. The public sector had a quota to achieve meanwhile being uncertain about the finance whereas the contractors had a main goal that is to survive, their only option was milking a sick cow to the last drop. The majority of contractors are categorised as small or medium size companies that lack resources and expertise essential to implementing the change. Computers are mostly used for word processing and simple packages like MS Project or simple spreadsheets (Excel) are in some companies beyond the capabilities of staff.

For so long, cost estimating was simply the process of calculating the total cost of a project, usually performed by quantity surveyors, based on either Single Unit estimates like cost per unit area, number of beds, number of students, number of spectators or by adding up the estimated prices of all items of the bill of quantities. The former mostly used at the initiation phase (feasibility or sketch design) to run a feasibility study whereby an accuracy of up to 25% variation is accepted. The latter on the other hand is used at a later stage when a detailed design is achieved and an accurate estimate is required before the tendering stage. The contractors' price will be the clients' cost, yet often the two terms are used interchangeably. Usually the main concern of both parties (client and contractor) focus on estimating the total expenditure required by the client. Hypothetically, the accuracy at this stage should fall within the range of 5-10%; still in practice, up to 15% is regarded as acceptable. So far, in many developing countries like Egypt, this approach is the most popular despite all the research done on construction cost modelling.

Flanagan and Norman (1983) investigated the accuracy and monitoring of quantity surveyors price forecasting for building work. They regard that any forecasting process will involve error for mainly four reasons; a) forecasting is not an exact science, it is heavily dependent upon the availability of historical price data, professional expertise and judgment; b) historical data may be defective; c) at the

design stage ambiguity in the design and ambiguity in the price forecast go hand in hand; d) the variability in unit price rates contained in the bill of quantities.

Neil Morrison (1984) examined the accuracy of cost estimates prepared by quantity surveyors during the design stage and concluded that those estimates are not sufficiently accurate to meet all the objectives of cost planning. Morrison suggested developing other methods using large cost databases. His suggestion seemed to focus on the importance of sample size or availability of data but falls short of giving insight to what methods and techniques should be applied as most appropriate to enhance the accuracy of what seems up-to-date as the most popular prevailing technique in construction cost estimating especially in Egypt.

Shash and El Khaldi (1992, cited in Akintoye and Fitzgerald 2000), identified the factors affecting the accuracy of cost estimating as financial issues, bidding situations, project characteristics and the estimating process itself. Yet the main factor as responsible for the accuracy of cost estimates irrespective of the size of contractors was the previous experience of the contractor on the type of project. This factor was followed by anticipated or frequent delays in periodic payments, type and size of contract and project location. The latter was elected as one of the main independent variables in the estimated model as introduced later in this study.

Raftery (1991) classified techniques of business forecasting into three categories; a) qualitative, (e.g. Delphi technique), b) time series that predict future values of a variable from observations of its historical behaviour using mathematical exploration and taking into account, trend, seasonality and cyclicity, c) causal methods (e.g. regression and/or correlation analysis). Raftery stated that cost models can be classified into three generations whereby the second generation, which began around the mid 1970s, was characterised by intensive use of regression analysis.

Bowen and Edwards (1985) mentioned that regression models have emerged as the most popular techniques after Tregenza (1972), Kouskoulas and Koehn (1974), McCaffer (1975), Reynolds (1978; 1980), Flanagan and Norman (1983), Bowen (1982; 1984) and others. Bowen and Edwards pinpointed the superiority of these models and wondered why they were not widely applied in practice or adopted by the industry. Moreover, regression analysis, used in this paper, has been applied by many researchers; Neale and McCaffer (1974); Ashworth *et al.* (1980); Akintoye and Skitmore (1994); Songer and Molenaar (1997); Smith (1999); Ameen *et al.* (2003) and others.

## DATA ANALYSIS

A sample of 118 schools built in the period from 1995-2003 was collected. The sample included schools built in different locations in 13 governorates (provinces), spreading from Upper Egypt (Luxor, Qena) to the Northern Coast. The main characteristics of the standardised design applied may be summarised as follows: 1) the main building is a multiple of a fixed module; 2) the skeleton specifications are the same in terms of material and statement of work; 3) the finishing specifications are the same in terms of material used and statement of work.

The elimination of the data of foundation, landscape and other facilities that vary from one school to the other is intended to bring focus on the super structure of the main building where the standardised design applies. In the majority of schools the main building accounts to more than 80-90% of the total project cost.

Salama *et al.* (2005) found that macroeconomic variables are significant predictors of project cost even after accounting for project physical variables. The macroeconomic variables investigated were Egypt's GDP, interest rates and exchange rates (\$ vs. L.E.), both official and unofficial rates, US GDP and interest rates due to the strong ties between both countries in terms of economic influence. The Egyptian currency like some other Middle-East currencies is strongly related to the U.S. Dollar.

The most significant macroeconomic variables were found to be:

1. the divergence between the official and unofficial exchange rates,
2. the ratio of the Egyptian GDP to the US-GDP, and
3. the Egyptian interest rate. Therefore, these three variables were elected as the macro-economic variables in this study.

Moreover three product variables were included:

1. the location of the project as a dummy variable with two values one for urban and zero for rural locations,
2. the quantity of reinforced concrete in the skeleton (main building) and
3. The total cost of all other items in the main building excluding concrete works.

Variables 2 and 3 are proxy to the size of the project since the design is standard. Excluding the concrete works was an attempt to reduce the degree of multicollinearity. However, due to the standard design, correlation might be inevitable but it is not exact (perfect) correlation due to the differences in specifications of the finishing items. Location is by and large the most important single factor that causes these differences. Coastal sites usually imply different types of material than inland urban or rural areas (Oases). Rural projects are perceived to include additional costs for transport of material and accommodation of people. This factor does not seem to be recognised by GAEB price lists whereby any item has a single unit price regardless the location of the site. The model is estimated using ordinary least squares (OLS) regression. To normalise the data, and to aid interpretation of the coefficients, a log-log functional form is used. The underlying objective is to test the hypothesis that the elected variables are significant predictors of the mark-up. Then the training and testing of the model will determine the predictive accuracy. Only 105 samples were used in the model estimating and training as 13 samples were randomly chosen for testing the estimated model.

The simple initial model included the natural log of the mark up as the dependent variable. A vector of explanatory variables measure variation in project size and design while a set of macro economic variables proxy economic trends and conditions both in Egypt and in the United States. All time series macro variables were also measured in natural logs. After running the first regression, it became clear that the quantity of concrete in the skeleton and the total cost of all other items in the skeleton were highly correlated as shown in Table 1. One possible solution to the possibility of multicollinearity is to drop combinations of variables that are highly collinear with other predictors (Salama *et al.* 2005). The total cost of skeleton was omitted as it had the lowest tolerance meanwhile keeping an eye on R square. The latter remaining unchanged as shown in Table 2 suggested that either the omitted variable was insignificant or its effect might have been overshadowed by the correlated variable; the quantity of concrete in the skeleton.

**Table 1:** Preliminary estimation results

Variable	Label	Coefficients	t_statistic	Tolerance
(Constant)	Constant	6.13	11.01	
Location	Location	-1.04	-23.81	0.65
Ln_QRC	Quantity of RC in Skeleton	0.05	1.56	0.10
Ln_CostSK_w_CQRC	Cost of Skeleton excCRC	-0.06	-1.55	0.09
Ln_ratio_Egy_US_GDP	Ratio of EGY_GDP to US_GDP	0.01	0.08	0.20
Ln_Egy_Int_Rate	Int. Rate in Egy	-0.62	-5.14	0.37
Ln_ratio_unoff_off_ex	Ratio of Unoff to Off. ex.Rate	-2.74	-16.82	0.37
R square		0.94		
Adj R sq.		0.94		
F statistic		254.60		

**Table 2:** Preliminary estimation results (Reduced Data- step 1)

Variable	coefficient	t_statistic	Tolerance
(Constant)	5.57	13.04	
Location	-1.08	-30.00	0.97
Ln_QRC	0.00	0.29	0.96
Ln_ratio_Egy_US_GDP	-0.01	-0.09	0.21
Ln_Egy_Int_Rate	-0.59	-4.92	0.38
Ln_ratio_unoff_off_ex	-2.73	-16.64	0.37
R square	0.94		
Adj R sq.	0.94		
F statistic	300.75		

**Table 3:** Preliminary estimation results (Reduced Data- step 2)

Variable	coefficient	t_statistic	Tolerance
(Constant)	5.60	13.73	
Location	-0.75	-30.13	0.97
Ln_ratio_Egy_US_GDP	-0.01	-0.08	0.21
Ln_Egy_Int_Rate	-0.59	-5.02	0.38
Ln_ratio_unoff_off_ex	-2.73	-16.78	0.38
Adj R sq.	0.94		
F statistic	379.39		

**Table 4:** Final Estimation Results

Variable	coefficient	t_statistic	Tolerance
(Constant)	5.63	24.68	
Location	-1.08	-30.35	0.98
Ln_Egy_Int_Rate	-0.59	-6.85	0.72
Ln_ratio_unoff_off_ex	-2.74	-23.67	0.74
R square	0.94		
Adj R sq.	0.94		
F statistic	510.87		

To test the effect of both variables, the latter was omitted as well as shown in Table 3. Interestingly, R square was not affected suggesting that both variables no matter how correlated had no significance as predicting variables for the dependant variable; the mark-up. Moreover, the ratio of the Egyptian GDP to the US GDP needed further attention. A relatively low tolerance and t statistic values suggests the presence of multicollinearity. The variable was omitted to investigate its effect.

Table 4 shows that the value of R square was not affected by omitting the GDP variable meanwhile both t statistic and tolerance values improved significantly. The results reflect two main findings. First, the relatively high tolerance and t statistic values coupled with the high value of R square suggest the effectiveness of the data reduction approach applied indicating that both physical variables in addition to the ratio of GDP<sup>rs</sup> proved to have negligible effect in predicting the value of the mark-up. Second, the increase in value of F statistic means that the predictive function of the model in the last round (Table 4) is more accurate than the previous three rounds (Tables 1, 2 and 3). Relatively high F statistic value means that the estimated model can predict the dependant variable more accurately than its mean value. To verify the results before proceeding to the training and testing of the model, two further trials were attempted. The elimination of the interest rate variable reduced the value of R square down to 91% from 94%. The further elimination of the only remaining macro variable; the divergence between unofficial and official exchange rates caused R square to drop from 91% to 57% elucidating the dominance of both the location and the exchange rate as the most influential variables compared to the negligible effect of some other variables on the value of R square as illustrated in Tables 1, 2 and 3.

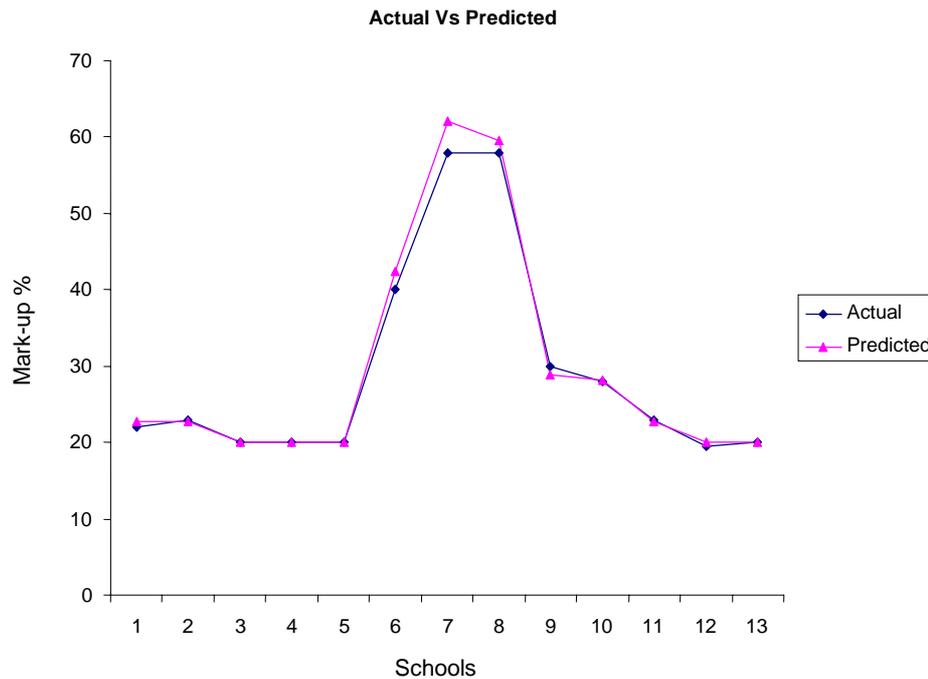
The training of the model using 105 samples showed accuracy level of 96.6%. The training of the model using 105 samples showed accuracy level of 96.6%. The model was then tested using a data set comprises 13 schools and showed an accuracy level of 97.7% as shown in Fig.(1) compared to the actual mark-up.

## LIMITATIONS OF THE STUDY

The study has some limitations that can be summarised as follows:

The assumption of the consistency of the cost estimating process by GAEB quantity surveyors.

The assumption that the main building accounts to 80% or more of the total project cost. Hence the variability in other components of the projects will not be dominant in shaping the mark-up requested. This is the case with school building in Egypt whereby if the costs of foundation for instance will be too high the whole site is abandoned in search for a more feasible location.



**Figure 7** Actual mark-up and model prediction

The assumption that bidders are rational with no biased decisions when asking for mark-up. The fact that GAEB has the right according to the Egyptian regulations to reject any offer coupled with the numerous and yet similar projects tendered concurrently render this assumption reasonable for the case study in hand.

## CONCLUSIONS AND FURTHER DIRECTIONS

The paper aimed at modelling the relationship between the key independent variables that can accurately predict the value of mark-up (dependant variable) requested by bidders for school buildings in Egypt. The paper applies a simple approach of data reduction that despite quite simple proved to be effective. This study reflects on the work of Salama *et al.* (2005) that applied an advanced analysis using principal component analysis and varimax rotation technique to investigate the effect of the macro-economic variables on the cost of project for school buildings in Egypt. In this study, the mark-up was elected as an a dependent variable rather than the project cost yet the study benefited of the previous findings with regard to the most significant macro-economic variables namely 1)the divergence between the official and unofficial exchange rates and 2) the Egyptian interest rate level. The following points are the main conclusions of this study:

The study shows that when the design is standardised, the project size does not have significant impact on the mark-up requested by bidders.

The study highlights an important advantage of applying standardised design with regard to controlling cost variances and enhancing the accuracy of cost estimating having neutralised the effect of the project specific variables.

The standardisation of design has contributed to the ease of the cost modelling. The simplicity in technique and limited number of variables used in the estimated model in this study should help more practitioners to comprehend and hopefully implement the model.

The location of the project site on the other hand is significant in shaping the decision of the bidders with regard to the mark-up. However, this factor seems neglected by GAEB.

The macro-economic variables are significant in predicting the mark-up level. The divergence between the official and unofficial exchange rates reflects conditions that call for devaluation in the Egyptian currency and where those conditions are not met by an official devaluation, the bidders hedge against any unfavourable consequences by price adjustments reflected in the level of mark-up.

Also, for further directions:

- Future specifications of the model will include lagged time series variables in an attempt to capture dynamic adjustment.
- Consideration will be given to extending the length of time series.

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