Cost Entropy and Expert System Approach to Modeling Cost Smoothing System in Reinforced Concrete Office Building Projects Procurement

Lekan Amusan M. (Corresponding Author *Building Technology Department College of Science and Technology,Covenant University, Cannanland, PMB 1023 Ota. Nigeria (lekan.amusan@covenantuniversity.edu.ng) 234-(0) 8030743025*)

Anosike Michael N. *Building Technology Department College of Science and Technology, Covenant University, Cannanland, PMB 1023 Ota. Nigeria (nwa_4ch@yahoo.com) 234-(0) 8037044559*

Joshua Opeyemi. *Building Technology Department College of Science and Technology, Covenant University, Cannanland, PMB 1023 Ota. Nigeria (joshua.opeyemi@covenantuniversity.edu.ng)*

Adelakun Adegbenjo. *Building Technology Department The Polytechnic Ibadan Saki Campus Oyo State Nigeria 08075508565*

Owolabi Dele J. *Building Technology Department College of Science and Technology, Covenant University, Cannanland, PMB 1023 Ota. Nigeria (james.owolabi@covenantuniversity.edu.ng*

Abstract

The main aim of this research work is to develop an expert system approach to cost smoothing model in reinforced concrete office building project procurement. An econometric model which incorporates exigency escalator and inflation buffer, with entropy threshold for a typical reinforced concrete office building, useful at tendering and construction stages of building projects was developed in this study. As built and bill of quantity value of twenty (20) building projects initiated and completed within 2008 and 2009 were used at random. Elemental dichotomies within the context of early and late constructible elements with speculated prediction period was used, taken into consideration the present value of cost. This attributes would enable a builder or contactor load cost implication of an unseen circumstance even on occasion of deferred cost reimbursement with the aid of average entropy index developed for each project elements. The model was further validated with new samples and discovered to be of high Eigen and contingency coefficient values. The model could help in cost smoothing at different stages of reinforced concrete office building which could further aid cost overrun prevention.

Keywords: Expert system, Smoothing, Entropy, Dichotomy.

1.1 Introduction

Monitoring project cost is an essential part of projects' life cycle. It enables early detection of problem area that may hinder timely project completion. However, ineffective project cost monitoring system can jeopardize the expectation of clients in obtaining value on money invested (Mosaku and Kuroshi 2008). The consciousness of this fact has made client to always be down–to-earth when it comes to issue of project cost. The need to enable client obtain adequate return on investment has lead to the emergence of different schools of thought in project procurement system; there are schools of thought described as traditional school of thought and non-traditional procurement system. In traditional procurement system's school of thought; there is allowance for client having absolute control on determination of issues that pertains to policy direction formulation, direct labor utilization, labor only deployment system among others. Non-traditional procurement system school of thought differs a little from the traditional system, in that, issues about policy determination and site procedural settings are mainly executed by professional groups in line with clients' requirement unlike the former. The multi-participative nature of the latter has situated it as the best procurement system globally. However, irrespective of procurement system adopted, there is always the need to evaluate the cost of the project component before commencement of work, this is necessary to avoid delay in payment. Also, multidisciplinary dimension introduced through innovations and ideas often leads to cost variation on site and other unforeseen events that can create project cost imbalance, this tends to situate builders and other project professional on negative side, since it often leaves the builder to continue the project on account of their profit (Christidolou 2008). Moreover, in recent times, considering the capital intensiveness nature of office building projects, creating a system that will ensures consistent fund flow, and accommodate economic variants that influences project cost is essential. Some of the methods include elemental cost harmotization and cost smoothing among others (Williams 1994, Moselhi et al; 1994, Jain et al; 2002). Cost smoothing ensure effective spreading of fund across all the project elements, this ensure consistent fund availability even on occasion of delay in fund disbursements (Amusan et al; 2012). Therefore a system that accommodates unforeseen intervening variables that often accounts for cost variation that could facilitate meaningful cost pattern deduction in project cost monitoring and project cost progress evaluation is presented in this context. It is to this end that this research work developed an econometric cost smoothing system for office building works using expert system approach with a base in cost entropy (Amusan et al; 2012). This model will make it possible for a project cost variants to be incorporated into project cost in order to buffer the effect of possible delayed payment on a project.

1.2 Concept of Cost Smoothing (Cost Balancing)

Concept of cost smoothing has been in existing since the ancient time of old Babylonian empire when towers were built and era of building Rameses in Egypt. Since then, services of cost experts have been found invaluable. However, since then, and towards the beginning of twenty-century, cost valuers had used various valuation methods of which regression analysis is the major method. Albeit, in recent times, more sophisticated methods have been developed in order to forestall incidences of undervaluation of project elements. Such method includes; exponential cost smoothing, bid-balancing method among others. Bid-balancing according to Cattel, Bowen and Kaka (2007) is described as the method in which cost is spread differentially on project elements without differential allocation. There are three different types of approaches in bid-balancing and cost smoothing; the front end loading system, Back-end loading system and Individual loading system.

Front-end loading approach is the system that tends to compensate a builder in situation of inflation or deflation by spreading cost of building item evenly. This is achieved by loading future worth of an item on its cost at bidding stage. The negative effect of inflation or deflation would have been cushioned in this regard. It tends to enable high cost to be factored on items billed to be executed at the early part of the project life cycle (Cattel et al., 2008).

Back-end loading on the other hand entails monetary loading of items of work scheduled to come up later on a project with high cost, considering the financial state as at time of cost loading relative to the period of execution. This type of system is often discouraged unless there is an assurance of consistent fund flow on a project. This type of approach is however not suitable for adoption in an environment where price fluctuations is the order of the day.

However, individual–rate- loading takes selective cost treatment of individual project items. The items are treated individually and rate composed considering prevailing economic situation. In this school of thought price can be controlled on each item, this makes identification of problem area easy and enables corresponding cost inference to be easily drawn from project items. Moreover, in appraising the advantages and disadvantages of each price loading system mentioned, it would be discovered that they are somehow interrelated in function and structure therefore contingency approach is better, this enables combination of one or more of the methods to achieve the desired results since no single method is sufficient to produce desire results in a system.

1.3 Understanding Elemental Cost Entropy

Entropy in the real sense of it is a concept that describes the rate of exchange of kinetic energy in the matrix of a substance. It is an index used to measure the degree of restiveness of compound molecules. Molecules in construction project parlance typified project cost centers, kinetic motion therefore could be likened to the nature and degree of cost movement pattern on a project, cost entropy therefore could be described as an index of cost movement pattern among project price items. Elemental cost entropy therefore could further be described as the study of cost movement among project elements with the aim of identifying movement index and price activeness (Christopher 2008). Entropy is described by Christidolou (2008) as a measurable concept; it is regarded as a function of project elements probability inverse being considered. Entropy is often measured on completion cost of project. Entropy could as well be measured through considering the influence of project elemental cost on the final completion cost of projects. Against this background, the influence of the cost centers on final completion was valued and probability quantified with a view to determining cost entropy state of the project cost elements.

Table 1.1 Quantificating Project Elemental Cost Entropy

Elements	Reinforced Concrete Office Units 2009[A] [₦Million]	Reinforced Concrete Office Units 2009[B] [₦Million]	Reinforced Concrete Office Units 2008[A] [₦Million]	Reinforced Concrete Office Units 2008[B] [₦Million]
Substructure	29,958,952	40,926,908	19,477,075	40,556,395
Frame & Walls	41,899,114	5,723,357	27,239,678	56,720,176
Stair Cases	3,256,408	4,448,577	2,117,074	4,408,304
Upper Floor	18,452,978	25,208,603	11,996,749	24,980,389
Roofs	15,847,852	21,649,742	10,303,091	21,453,745
Windows	11,723,069	16,014,877	7,621,465	15,869,894
Doors	11,940,162	16,311,449	7,762,603	16,163,781
Finishing Works	33,432,454	45,672,057	21,735,287	45,258,586
Fittings	3,907,689	5,338,292	2,540,489	5,289,965
Services	15,413,664	21,056,598	10,020,814	20,865,972
Soil Drainage	4,558,971	6,228,008	2,963,903	6,171,626
Preliminaries	9,552,130	13,049,159	6,210,082	12,931,025
Contingencies	6,729,910	9,193,726	4,375,850	9,110,495
ValueAdded Tax (5%)	10,420,505	1,423,5446	6,774,635	14,106,572
Sum	N217,093,858	296,571,798	141,138,227	293,886,923

Entropy is a measurable phenomenon; it is often premised on price movement. This is measured in the context of construction project using fourteen (14) project elements of twenty (20) projects average as case study. The project includes those initiated and completed within 2008 and 2009. The bill of quantity value (Tender sum) and As-built cost (completion cost) were used for the analysis. Average residual entropy for individual project was calculated and presented in Table 1.1. Slightly moderate negative correlation exists among the cost elements of project executed in 2008 as presented in Table 1.2. This is attributable to impact of economic meltdown that induced price variation while moderate positive correlation exists among elements of 2009 projects. Generally, simulating 2008 and 2008 projects, positive correlation (high) exist between the two years.

Furthermore, Average Residual Entropy was calculated by finding the ratio between individual elements of project (A) for the year being considered and total cost summation of similar elements in the bill of quantity. Average Residual Entropy per year is derived by dividing the cost of individual projects of the year in consideration by cost summation of elements in the bill of quantity, detail is in Table 1.3. Entropy phenomenon is relative in nature, therefore it could be said that cost entropy depends on a number of factor, this includes prevailing economic situation, demand and supply of material, macro and micro economic variable among others. However, in the light of dynamic nature project element- cost composition, there is a need to device a method of studying the minute detail of the movements as they occur. Therefore, in this research work, an econometric approach to the price movement monitoring with the aid of cost variable and Artificial Neural Network is presented.

Table 1.2 Quantificating Project Elemental Cost Entropy

Cost Rating Scale: One(1) to Ten (10)		
Elements	Average Residual Entropy Index Office Units2009 [₦Million]	Average Residual Entropy Index Office Units 2008 [₦Million]
Substructure	0.423/0.015	0.6488/0.117
Frame & Walls	0.423/0.015	0.6488/0.163
Stair Cases	0.423/0.015	0.6488/0.013
Upper Floor	0.423/0.086	0.6488/0.072
Roofs	0.423/0.072	0.6488/0.042
Windows	0.423/0.055	0.6488/0.044

Doors	0.423/0.055	0.6488/0.046
Finishing Works	0.423/0.154	0.6488/0.132
Fittings	0.423/0.018	0.6488/0.016
Services	0.423/0.025	0.6488/0.060
Soil Drainage	0.423/0.011	0.6488/0.018
Preliminaries	0.423/0.049	0.6488/0.037
Contingencies	0.423/0.031	0.6488/0.026
ValueAdded Tax (5%)	0.423/0.052	0.6488/0.041
Sum		

Table 1.3 Elemental Average Residual Entropy

Statistical Parameters	Residual Entropy Index 2008	Residual Entropy Index 2009	Office Unit 2008 and 2009
Correlation	-0.553	0.507	0.756
Significance	0.447	0.493	0.244
Degree of Freedom	2	2	2

Average Residual Entropy for individual project is calculated in Table 1.2 by finding the ratio between individual elements of project(A) in the year in consideration by summation of total cost of similar elements(A and B) in projects being considered. Average Residual Entropy per year is derived by dividing the cost of individual projects of the year in consideration with summation of cost of elements in consideration.

1.4 Dynamics of Monetary Entropy in Office Building Projects

Table 1.4 As-built and Neural Network Induced Price Movement

		1	2	3	4	5	6
	Project	A	B	C			
Cost Centers		BQV [₦Million]	AB V [₦Million]	NNACO [₦Million]	BOQ Base Entropy Value	As-Built Entropy Value	Neural Output Entropy Value
Project 1-10	1	217093854	300814387	412,797,416	1.000	1.386	1.370
Office	2	296571798	478737280	445,738,080	1.000	1.614	1.931
Building	3	141138227	155238227	465,329,444	1.000	1.100	2.998
2009	4	290928823	298956814	348,432,150	1.000	1.028	1.165
	5	216996254	220856000	394,547,922	1.000	1.018	1.787
	6	219887135	219887136	405,878,924	1.000	1.004	1.846
	7	220768961	299672863	323,622,889	1.000	1.357	1.080
	8	220768961	225138124	438,200,127	1.000	1.020	1.947
	9	231136821	233268148	315,232,642	1.000	1.009	1.352
	10	215783222	218112136	478,307,495	1.000	1.011	2.193
Project 11-20	11	293886923	294986520	328,522,229	1.000	1.004	1.114
Office	12	294693872	296700622	327,022,716	1.000	1.001	1.102
Building	13	219784963	220825120	406,183,226	1.000	1.005	1.839
2008	14	286668982	288700000	328,522,228	1.000	1.007	1.138
	15	225513614	230525000	327,022,717	1.000	1.022	1.419
	16	288996713	289885120	327,169,021	1.000	1.003	1.129
	17	218682814	220350000	334,397,421	1.000	1.008	1.518
	18	287981813	293650000	363,394,497	1.000	1.020	1.238
	19	219822673	221762000	319,290,903	1.000	1.009	1.440
	20	271136048	271948000	334,397,421	1.000	1.003	1.230

Legend: BOQVal—Bill of Quantity value, ABV—As Built Value, NNACO—Neural Network Adjusted Cost Output Value.

Dynamics of cost movement in the sampled projects is presented in Table 1.2; the cost movement was formulated with the aid of As-built entropy value and Neural network output-entropy value (Hegazy et al; 1993). As-built entropy value was derived by finding the quotient of As-built value relative to Bill of quantity base value. However, Neural output entropy value was synthesized by using As-built value as the base cost, the quotient is obtained by dividing the Neural output value by As-built cost value of the project.
As-built value was adjusted with prevailing inflation index as at the end of second quarter

of the year 2012. The output was loaded onto a carefully selected Neural network algorithm (Back Propagation method with Genetic Algorithm). The output was compared to other two values (as-built value and bill of quantity value). It was revealed that highest value of entropy was obtained among projects executed in the economic meltdown era, with index 2.998 and 1.913 respectively. Also, highest As-built value is obtained among 2009 executed projects. This validated submission in Table 1.2 where entropy values for each project were quantified. Highest entropy of 0.154 was achieved against base value of 0.423 on scale 1.1 to 1.0 for finishing works. The reason that accounts for this trend could be linked to importation challenge that surrounds the procurement of most of finishing items. The economic meltdown induced rise in cost of materials and other essential items used in project execution, considering the flexible nature of the elemental cost, contractor or client must have a system that would accommodate economic variables as depicted by the entropy movement. An attempt has been established in obtaining a permanent pattern of variation which was achieved through the use of neural network. The as-built value was modified with inflation index of 11.4% and building index value of 10%, this was loaded onto neural network with genetic algorithm. The resultant economic variables were later factored into the econometric model generated.

Table 1.5 Econometric Factor Adjusted-Project Elements (Office Units)

Element	Tender Cost[₦]	Tagged Project Cost[₦]	Front-end Loading [₦]	Individual-rate loading[₦]	Econometric Model Loading [₦]
Substructure	29,958,952	217,093,858	33811133.3	8274962.1	2,939,503.90
Frame & Walls	41,899114	217,093,858	93,681,043.00	419,672.62	46,139,585.70
Roofs	15,847,852	217,093,858	46,405,804.70	987,525.00	17,451,813.5
Windows	11,723,069	11,674,519.50	84,600,278.7	3,238,029	12,909,562
Doors	544,500	11,674,519.50	3,726,665.30	150,396.40	599,609.10
Finishing	2,541,535	11,674,519.50	3,058,058.00	701,997.38	2,798,763.80
Fittings	298,800	11,674,519.50	3,8018,925.70	82,531.60	329,041.60
Services	786,350	11,674,519.50	312,645,694.00	217,198.00	865,936.80
Soil Drainage	274,000	11,674,519.50	3,817,228.70	75,681.54	301,731.54
Preliminaries	500,000	11,674,519.50	3,741,563.90	138,105.00	550,605.00
Contingencies	270,000.0	11,674,519.50	3,818,567.90	74,576.7.00	297,326.70
Value Added Tax (5%)	555,929.50	11,674,519.50	3,722,838.70	153,553.30	612,195.20

An econometric cost factor model was developed in this context to generate cost output and compared with other two types of loading system like Front-end loading, Individual rate loading and the modified form of back-end cost loading system of Cattel, Kaka and Bowen (2008)

$$pvj = \sum_{n=0}^{N} \left(\frac{1}{1-r}\right)^{n} [\lambda njQj\,(Pj - Cj)]]$$ (Cattel et al., 2008)

.Structural Component of Neural Network Econometric Modified Back-End Loading Approach is as described thus: $[\Sigma\,(1/1\text{-}r\,)^n\,]([\,C\lambda_{nj}\,[\,Q_j + Q_i\,][\gamma_{nj} fP_j - C^1)] + \lambda_{nj}\,[\,Q_j + Q_i\,][\gamma_{nj} fP_j - C^1)]\,)$

The Back-end econometric model $[\Sigma\ [(1\text{-}r\,)^n]\ ([\,C\lambda_{nj}\,[\,Q_j$ ____incorporates duration'n'and often used for factoring elements that has potential of being constructed later as the project progresses. In other to accommodate other elements schedule to be executed later in the project, an econometric factor $\lambda_{nj}\,[\,Q_j + Q_i\,][\,\gamma_{njnj} fP_j - C^1)]\,)$ need to be added. This factor incorporates inflation factor/index, and period in consideration together with variation factor anticipated.

Legend: rj --- monthly discount rate n --- month number C^1--actual increase in cost of items. λ_{nj} --- proportion of elements Q_j; Q_i ---- bill cost of iitem i, j γ_{nj} --- adjustment for escalation fP_j----Haylet Factor (0.85) C^1 ---- unit cost of item j.

This econometric model was validated by comparing the output of cost loading system and loading attributes as in Tables 1.4 to 1.8. Econometric model displayed the most reliable output, since the model incorporates econometric variant and over a period 'n' which makes it futuristic. Comparative analysis of loading attributes was further validated in Table 1.5.

1.6 Validating Neural-network Econometric Entropy-based Model Using Comparative Analysis of the Econometric Loading Attributes

Table 1.6 Cost Limit Component Validations

Elements and Statistical Parameters -	Reinforced Concrete Unit 2009	Reinforced Concrete Unit 2008	Residual Entropy Index 2008	Residual Entropy Index 2009
Reinf.Conc Unit 2009 Pearsons Corr.	1.00	-	-	-
Sig.(2-tailed)	0.00	-	-	-
Reinf.Conc Unit	0.787	1.00	-	-

2008 Pearsons Corr.				
Sig.(2-Tailed)	0.001	0.000	-	-
Residual Entropy Index 2008 Pearsons Corr.	0.764	0.905	1.000	-
Sig.(2-Tailed)	0.001	0.000	0.000	-
Residual Entropy Index 2009 Pearsons Corr.	0.791	0.586	0.485	1.000
Sig.(2-Tailed)	0.001	0.028	0.079	0.000

There is a need to validate the model developed within the context of its functional parameters as demonstrated in Table 1.6. Strong positive relationship exist between cost limit of reinforced concrete office unit built in 2008, and residual entropy index 2008 with pearson coefficient of 0.485, this exist between the cost limit of residual entropy 2008 and entropy index 2009. However, averagely strong relationship is recorded as well in mapping reinforced concrete unit of 2009, entropy index 2009 and reinforced concrete 2008, with Pearson's coefficient of 0.764 and 0.586 respectively.

Table 1.7 Correlation Matrixes

	Statistical Properties	Front loading	Indivdual rate loading.	Back-end loading
Correlation	Front Loading	1.000		
	Indivdual Rate Loading	-.471	1.000	
	Backendload	-.468	.735	1.000
Sig. (1-tailed)	Frontloading		.163	.155
	Indivdual Rate Loading	.143		.045
	Back-end Loading	.145	.045	

Table 1.8 Total Variance Explained

Component	Initial Eigenvalues	Extraction Sums of Squared Loadings

	Total	Percentage of Variance	Cumulative Percentage	Total	Percentage of Variance	Cumulative Percentage
Front-end loading	2.111	60.382	70.382	2.111	70.382	70.382
Individual-rate loading	.634	30.119	90.502			
Back-end loading	.297	9.498	100.000			
Extraction Method: Principal Component Analysis.						

Table 1.9 Econometric Loading Attributes

Monte Carlo Technique 99% Confidence Interval		Value	Asymp. Std. Error[b]	Approx. Sig.	Sig.	Lower Boundary
Individual-rate Loading	Contingency Coefficient	.955	.233	1.000	1.000[a]	1.000
	Kendall's tau-c	.912	.000	.000	.000[a]	.000
Econometric Front-end Loading	Contingency - Coefficient	.95	.233	1.000	1.000[a]	1.000
	Kendall's tau-c	-1.00		.000	.000[a]	.000
Econometric Back-end Loading	Contingency - Coefficient	.962	.233	.233	1.000[a]	1.000
	Kendall's tau-c	1.00			.000[a]	.000

Generally, considering the output of cross validation exercise carried out, the Econometric-Back-end loading system demonstrates high degree of reliability with contingency-coefficient of 0.962 considering presentations in Tables 1.7 to 1.9.

Research Implications: This work has presented an econometric approach to loading all elements as being scheduled for implementation at the latter end of the project work. This is facilitated through inclusion of inflationary clause that covers period of 6 months. The system of loading will enable the contractor overcome price fluctuating shock, since the long term effect of inflation and other economy variant would have been factored into the cost at the project inception. Similarly, the research work has generated entropy factor for each element, this could as well be factored into the cost of the elements at the bidding stage.

1.7 Conclusion

An econometric model with a base in entropy and neural network modified loading attributes, which could be used in cost smoothing for office building is presented in this study. The econometric model would enable early factoring of potential cost threat into project cost at inception. A builder, contractor and clients can bill the cost component in advance, incorporating a cost buffer that will lessen the burden of sole bearing of the cost increase on the constructor. However, elemental works often scheduled for construction at the latter part of the project should be loaded with the likely anticipated increase to cushion the effect of the uncertainties when eventually occurred. Therefore an econometric model like the one presented in this study accommodates upward factoring of project elements cost, it accounts for present value of the cost using period 'n' in consideration as reference point. Considering presentation in Table 1.4, taking finishing work as a base for illustrations, econometric model presented ₦2,541,535 leaving a cost margin of ₦ 257,228.80. The margin could be built to the cost right at bidding stage taking delivery period into consideration. Also, the average entropy index of 0.143 for finishing work could be factored into the econometric cost value for consistency. This model is one of the means of curtailing the effect of cost overrun on project cost.

Amusan, L.M; Joshua , O; Owolabi J; Tunji-Olayeni, P; Anosike M.N (2012) Expert System-Based Exploratory Approach to Cost Modelling of Reinforced Concrete Office Building. *International Journal of Engineering and Technology.* 2(5).

Cattel,W.D., Bowen,P.A., and Kaka, A.P. (2008). A Simplified Unbalanced Bidding Model. *Construction Management and Economics*. 26(10-12), 1291-1302.

Christidolou, S.. A. (2007 September) Resource-Constrained Scheduling Using Ant Colony Optimization. Paper presented at the *Ninth International Conference on the Application of artificial Intelligence to Civil, Structural and Environmental Engineering.* St.Julian,Malta.

Christopher A. Z (2008) Entropy Financial Markets and Minority Games. *Statistical Mechanics and its Applications*. 388(7), PP 1157-1172.

Hegazy, T; Moselhi, O and Fazio, P (1993 October). "Managing Construction Knowledge in Patterns: A Neural Network approach". *Transactions of First International Conference in the Management of Information Technology for Construction,* CIB, Singapore.

Jain, A.K., and Mao, J. C, and Mohiuddin, K.M. (2002). Artificial Neural Networks, *Tutorial on Computer,* 29(3): PP 31-44.

Mosaku, T.O and Kuroshi, P.A (November 17 2008). "The Impact of Globalization on Housing in Nigeria.*" World Congress on Housing*. Kolkotta. India.

Mozelhi,O; Hegazy, T. and Fazio P. (1994). "DBID: Analogy-Based DSS for Bidding in Construction."*Journal of Construction Engineering and Management, ASCE,* 119(3), PP 466-479.

Murtaza, M., and Fisher, D. (1994). Neuromodex-Neural Network System for Modular Construction Decision Making. *Journal of Computing in Civil Engineering ASCE*, Proc. Paper No. 5708, 8, 2: PP 221-233.

William, T. (1994). Predicting Changes in Construction Cost Indexes Using Neural Networks. *Journal of Construction Management and Engineering, ASCE*. United Kingdom: Taylor and Franchis. 120 (2), PP 306-320.