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Whole Life-Cycle Costing of Proposed Building Projects in the Nigerian Construction Industry

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Abstract: The application of Whole Life Cycle Costing (WLCC) in the developing countries is handicapped by the shortage of funds and lack of adequate and reliable data. In an attempt to overcome these difficulties, an algorithm was proposed by the authors in the first series to this study. This study, which is sequel, examines the efficacy of the algorithm to find practical application in the Nigerian construction industry. To achieve this goal, the various data required for testing the algorithm and their sources were identified, collected, adjusted and used in testing the algorithm at different stages of design evolution. The results obtained confirmed previous assertions that, both uncertainty and the ability to influence cost decrease as design evolves. The main advantages of the algorithm are that; the quantity of data required are minimal and readily available; variables are expressed as 3 point data which may represent the range and mean or modal class of the variable in question; it is computationally efficient when compared with other techniques and it is flexible in terms of risk analysis and control. It is believed that, the algorithm will improve the usability of WLCC especially in the developing countries where lack of finance and scarcity in WLCC data are predominant.

Key words: Whole life-cycle costing, algorithm, triangular fuzzy numbers, benchmark, risk analysis (12390)

INTRODUCTION

According to Dell'Isola and Kirk (1981), the concept of Life Cycle Costing (LCC) originated in the United States outside the construction industry in the 1930s. The use of LCC in the construction industry was first recorded in the United Kingdom around 1960s. It evolved from Terotechnology from 1960-1969, to cost-in-use from 1970-1978, to LCC from 1979-1999 and finally Whole Life Cycle Costing (WLCC) from 2000 to the present (Boussabaine and Kirkham, 2004).

Whereas, the term has found extensive usage in the developed countries, it is hardly used in the developing countries. This is due to shortage of funds and lack of adequate and reliable historical data (Flanagan and Jewell, 2005). In Nigeria for instance, building projects are mostly evaluated on the basis of initial capital cost despite the fact that the operating cost of a hospital building, for instance, could consume an equivalent of the capital cost every 2-3 years and can continue to do so for 40 years or more and that of a school can consume the equivalent of its capital cost every 4-5 years and remain in service for a century (DPWS, 2001). This does not ensure accountability on public projects and does not give private developers best value for money. A WLCC model was proposed in a first series which addresses the problem of data scarcity and uncertainty based on Fuzzy Set Theory (FST). This study examines, the efficacy of this model to find practical application in the Nigerian Construction Industry.

MATERIALS AND METHODS

The data required for testing the model and their sources were first identified. A live project was selected based on which data was collected, adjusted/analyzed for use in the model. Cost data were collected using Building Cost Information Service (BCIS) 2006. Standard form of cost analysis and Building Maintenance Information's (BMI) Standard Form of Property Occupancy cost Analysis. The algorithm outlined by the authors in the first series was then followed to prepare WLCC of the proposed project at the various stages of the design evolution. Table 1 outlines the different classification of the data required, their sources and adjustments made to prepare them for use in the model.

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Table 1: Data types, Data sources and Adjustment made

Data types	Data sources	Adustments/analysis
General project information (e.g Project title, description and location)	Clients brief and project information	None
1. Inflation indices	Central Bank of Nigeria's yearly Bulletin (1995)	Forecast made over 30 year period using regression analysis and inflation rate determined there from. A percentile range was then applied to cover for future uncertainty.
2. Cost of borrowing (Borrowing rate)	Financial institutions	A range and likely value was identified from the data collected.
3. Analysis period	Client's brief and consultants' advise.	A percentile range was applied to cover for uncertainty
4. Capital cost/ Budget	Consultant quantity surveyor, Project brief, scale of fees, Development authorities, land and survey departments, financial institutions and state revenue office.	Where necessary adjustment for time and location were made and then a percentile range was applied to cover for uncertainty.
5. Operations cost	Published information from Building Maintenance Information (BMI), Text books, facilities/estate management firms	Where necessary adjustment for time and location were made and then a percentile range was applied to cover for uncertainty.
6. Maintenance cost	Published information from BMI, text books, maintenance manuals, Facilities/estate management firms	Adjustment for time, location and intensity of usage were made where necessary. A percentile range was established to cover for uncertainty
7. Salvage and residuals	Consultant quantity surveying and Estate management firms	Where necessary adjustment for time and location were made and then a percentile range was applied to cover for uncertainty.
8. Physical data (e.g. Gross Floor Area and other measurable quantities)	Client's brief and projects evolutionary design	None
9. Data reliability	Weighted evaluation of the sources of data and adjustment factors	None

Table 2: Breakdown of cost in use for various types of buildings

Type of annual cost	Houses	High flats	Industrial buildings	Schools	Offices
Maintenance cost (%)	14	12	18	16	13
Fuel and attendance for heating and lighting (%)	24	24	30	18	29
Initial costs					
(a) Building (%)	48	56	47	51	47
(b) Land and development (%)	14	8	5	15	11
Total cost in use (%)	100	100	100	100	100

Source: Seeley (1996)

RESULTS AND DISCUSSION

Model testing at inception stage: At this stage, the information available was mainly from the clients brief. The client has specified a budget of ₦ 95,000,000.00 for the initial capital cost, a minimum Gross Floor Area (GFA) of 1000 m^2 and a service life of 30 years. A bench mark was established from the client's budget using Table 2 against, which the WLCC was compared.

Figure 1 shows the generated membership functions for the economic variables and the discounting factors expressed as Triangular Fuzzy Numbers (TFN) while, Fig. 2 shows the membership functions for both the undiscounted and discounted cost data.

Table 3 is a summary of the lowest, likely and maximum Benchmark of costs for the various cost categories as derived from the membership functions above, while, Table 4 shows the range of values for the various economic and cost categories based on 50% data reliability.

Model testing at the feasibility stage: At this stage, the initial capital cost of the proposed project was recomputed based on historical data. Data from Table 2 was then used to recompute the various costs as shown in Fig. 3.

The summary of the WLCC plan at this stage is shown in Table 5 as computed from the membership functions in Fig. 3 and Table 6 shows the range of values for the various economic and cost categories at different data reliabilities.

Model testing at the outline proposal stage: An Outline design and preliminary specifications have been produced which give a clearer idea of the structure and shape of the building. Based on the Outline design the GFA of the building was about 1150 m^2 (575 m^2 each floor) and the total external area of the entire plot was 1085 m^2. In the light of the additional information the WLCC plan was updated and the output is shown on Fig. 4 and 5 and Table 7 and 8.

The Sketch design has been produced at this stage and the various elements of the building could be identified. Based on the design, the total GFA of the building is 1080 m^2. The Initial capital cost of the building was recomputed based on an elemental format.

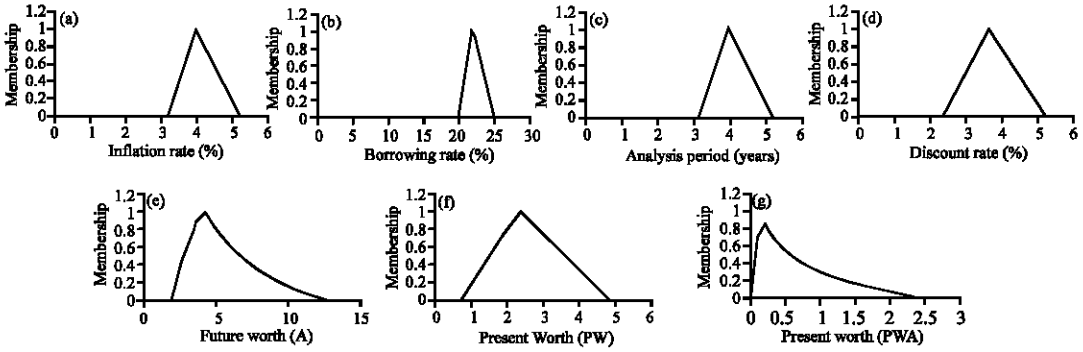

Fig. 1: Membership functions for inflation rate, borrowing rate, analysis period, discount rate, future worth, present worth and present worth of annuity

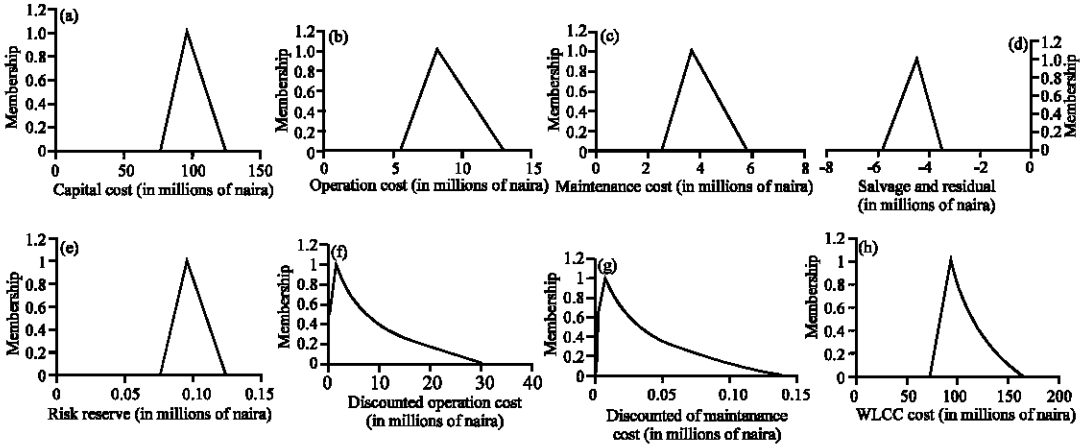

Fig. 2: Membership functions for capital cost, operations cost, maintenance cost, salvage and residual value, risk reserves, discounted operations and maintenance costs and WLCC

Table 3: A summary of benchmark of costs at the inception stage

Budget item	Minimum cost	Likely cost	Maximum cost
Capital cost	76,000,000.00	95,000,000.00	123,500,000.00
Finance cost per annum	0.00	0.00	0.00
Operation cost per annum	86,131.03	1,704,231.15	31,053,022.94
Maintenance cost per annum	38,610.46	763,965.69	13,920,320.64
Sundries	0.00	0.00	0.00
Salvage and residuals	-3,500,000.00	-4,500,000.00	-5,850,000.00
Risk reserves	76,000.00	95,000.00	123,500.00
Total WLCC (₦)	72,700,741.49	93,063,196.84	162,746,843.58
WLCC PER GFA	72,700.74	93,063.20	162,746.84

Table 4: Range of values for the various economic data and cost categories at 50% data reliability

Item description	Reliability value	Minimum value	Maximum value
Inflation rate (%)	0.50	3.57	4.56
Borrowing rate (%)	0.50	21.00	23.50
Analysis period(Years)	0.50	35	45.00
Discount rate (%)		2.96	4.37
Future worth factor (A)		2.78	6.84
Present Worth of Annuity factor (FWA)		0.06	0.71
Capital cost	0.50	85,500,000.00	109,250,000.00
Finance cost per annum		0.00	0.00
Operation cost per annum	0.50	406,493.01	7,510,797.27
Maintenance cost per annum	0.50	182,221.00	3,366,909.12
Sundries		0.00	0.00
Salvage and residuals	0.50	-4,000,000.00	-5,175,000.00
Risk reserves	0.50	85,500.00	109,250.00
Total WLCC (₦)		82,174,214.02	115,061,956.40
WLCC PER GFA		82,174.21	115,061.96

Table 5: Summary of costs at the feasibility stage

Budget item	Minimum cost	Likely cost	Maximum cost
Capital cost	65,632,656.25	79,509,781.25	94,678,437.50
Finance cost per annum	0.00	0.00	0.00
Operation cost per annum	74,381.69	1,426,347.85	23,806,086.57
Maintenance cost per annum	33,343.52	639,397.31	10,671,693.97
Sundries	0.00	0.00	0.00
Salvage and residuals	-3,500,000.00	-4,500,000.00	-5,000,000.00
Risk reserves	65,632.66	79,509.75	94,678.44
Total WLCC (₦)	62,306,014.11	77,155,036.17	124,250,896.49
WLCC PER GFA	62,306.01	77,155.04	124,250.90

Table 6: Range of values for the various economic data and cost categories at various data reliabilities

Item description	Reliability value	Minimum value	Maximum value
Inflation rate (%)	0.75	3.76	4.26
Borrowing rate (%)	0.90	21.80	22.30
Analysis period (Years)	0.75	38	42.50
Discount rate (%)		3.34	3.89
Future worth factor (A)		3.42	5.07
Present Worth of Annuity factor (FWA)		0.12	0.36
Capital cost	0.60	73,958,931.25	85,577,243.75
Finance cost per annum		0.00	0.00
Operation cost per annum	0.60	737,720.57	2,873,755.05
Maintenance cost per annum	0.60	330,702.33	1,288,235.02
Sundries		0.00	0.00
Salvage and residuals	0.60	-4,100,000.00	-4,700,000.00
Risk reserves	0.60	73,958.91	85,577.23
Total WLCC (₦)		71,001,313.07	85,124,811.05
WLCC PER GFA		71,001.31	85,124.81

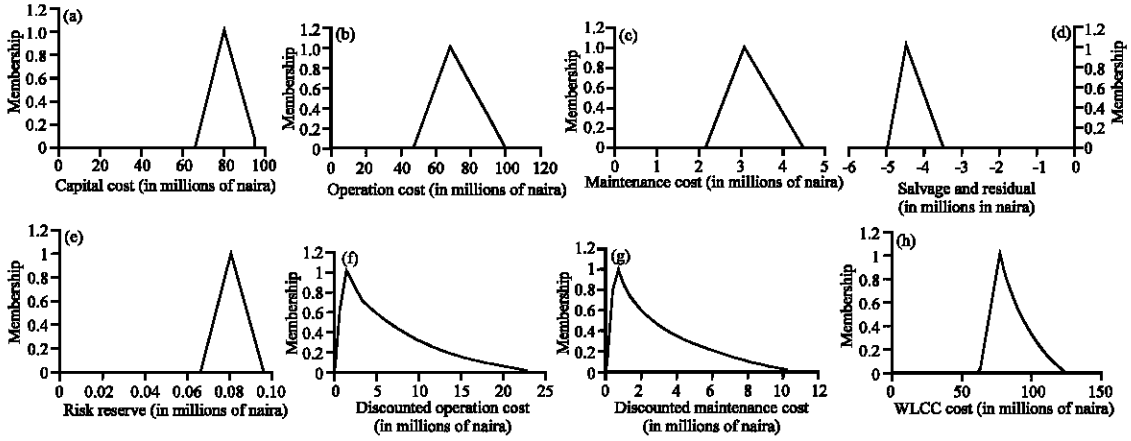

Fig. 3: Membership functions for the various cost categories, risk reserves, discounted operations and maintenance costs and WLCC

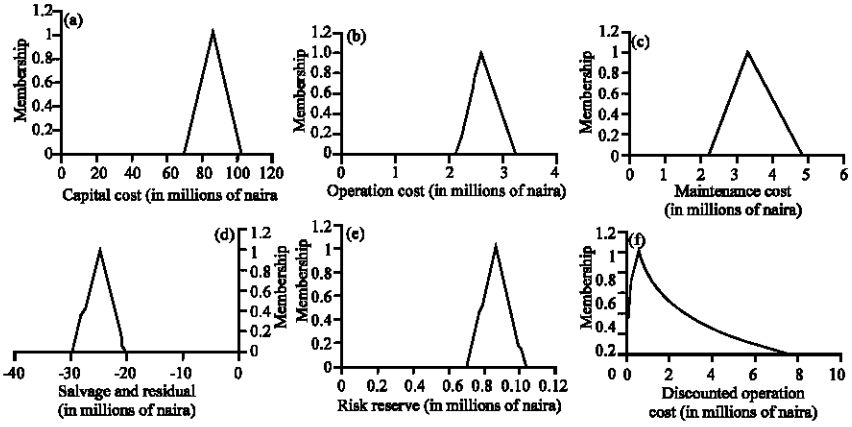

Fig. 4: Membership functions for the various cost categories, risk reserves, discounted operations costs

Table 7: Summary of costs at the outline proposal stage

Budget item	Minimum cost	Likely cost	Maximum cost
Capital cost	70,484,747.50	85,485,559.38	102,067,488.13
Finance cost per annum	0.00	0.00	0.00
Operation cost per annum	33,571.84	540,494.75	7,749,311.83
Maintenance cost per annum	34,455.44	687,452.99	11,504,439.20
Sundries	0.00	0.00	0.00
Salvage and residuals	-20,246,436.90	-24,746,389.90	-29,904,122.00
Risk reserves	70,485.75	85,485.56	102,066.49
Total WLCC (₦)	50,376,823.63	62,052,602.78	91,519,183.64
WLCC PER GFA	43,805.93	53,958.79	79,581.90

Table 8: Range of values for the various economic data and cost categories at various data reliabilities

Item description	Reliability value	Minimum value	Maximumvalue
Inflation rate (%)	0.75	3.76	4.26
Borrowing rate (%)	0.90	21.80	22.30
Analysis period(Years)	0.75	38	42.50
Discount rate (%)		3.34	3.89
Future worth factor (A)		3.42	5.07
Present Worth of Annuity factor (FWA)		0.12	0.36
Capital cost	0.70	80,985,315.82	90,460,138.01
Finance cost per annum		0.00	0.00
Operation cost per annum	0.70	301,828.53	990,074.11
Maintenance cost per annum	0.70	364,383.06	1,332,817.68
Sundries		0.00	0.00
Salvage and residuals	0.70	-23,396,404.00	-26,293,709.53
Risk reserves	0.70	80,985.62	90,459.84
Total WLCC (₦)		58,336,109.02	66,579,780.10
WLCC PER GFA		50,727.05	57,895.46

Table 9: Summary of costs at the scheme design stage

Budget item	Minimum cost	Likely cost	Maximum cost
Capital cost	56,179,636.32	69,919,353.92	90,526,372.58
Finance cost per annum	0.00	0.00	0.00
Operation cost per annum	26,959.70	676,839.21	9,608,135.00
Maintenance cost per annum	1,129.03	33,806.66	1,259,104.12
Sundries	0.00	0.00	0.00
Salvage and residuals	-15,496,863.40	-19,313,968.90	-25,030,562.70
Risk reserves	51,487.45	63,755.88	82,572.25
Total WLCC (₦)	40,762,349.10	51,379,786.77	76,445,621.25
WLCC PER GFA	37,742.92	47,573.88	70,782.98

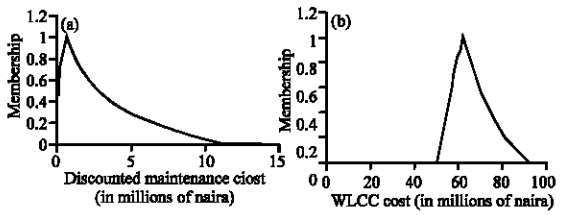

Fig. 5: Membership functions of discounted maintenance costs and WLCC

The Maintenance and Operating costs of the building were recomputed based on data collected on a similar building. The Maintenance costs of the various elements were computed by taking into consideration the life expectancies of these elements and their associated replacement costs. The WLCC plan was updated and the output is shown in Fig. 6 and Table 9 and 10.

Model testing at the detail design stage: The Detail design has been produced at this stage and all specifications at the Scheme design stage were confirmed to be unchanged. Additional information regarding services installation and details of finishes were specified by the design team. The maintenance cost was adjusted to reflect the changes as shown in Fig. 7 and Table 11 and 12.

Comparison of wlcc plan at the different design stages: Figure 8 is a presentation of the minimum and maximum WLCC at different stages of the design. It may be observed from the Fig. 8 that, as the design evolves from inception through to detail design stage, the WLCC and the differences between the maximum and minimum WLCC values also decrease. The variability of WLCC at different design stages is shown in Fig. 9. It may be observed that the variability reduces from about 40% at the feasibility

Table 10: Range of values for the various economic data and cost categories at different data reliabilities

Item description	Reliability value	Minimum value	Maximumvalue
Inflation rate (%)	0.75	3.76	4.26
Borrowing rate (%)	0.90	21.80	22.30
Analysis period (Years)	0.75	38	42.50
Discount rate (%)		3.34	3.89
Future worth factor (A)		3.42	5.07
Present Worth of Annuity factor (FWA)		0.12	0.36
Capital cost	0.70	65,797,438.64	76,101,459.52
Finance cost per annum		0.00	0.00
Operation cost per annum	0.70	342,276.74	1,235,544.55
Maintenance cost per annum	0.70	16,581.13	96,484.12
Sundries		0.00	0.00
Salvage and residuals	0.50	-17,405,416.15	-22,172,265.80
Risk reserves	0.70	60,075.35	69,400.79
Total WLCC (₦)		48,810,955.71	55,330,623.18
WLCC PER GFA		45,195.33	51,232.06

Table 11: Summary of costs at the detail design stage

Budget item	Min. cost	Likely cost	Max. cost
Capital cost	56,179,636.32	69,919,353.92	90,526,372.58
Finance cost per annum	0.00	0.00	0.00
Operation cost per annum	26,959.70	676,839.21	9,608,135.00
Maintenance cost per annum	1,269.27	35,695.02	1,218,218.97
Sundries	0.00	0.00	0.00
Salvage and residuals	-15,496,863.40	-19,313,968.90	-25,030,562.70
Risk reserves	51,487.45	63,755.88	82,572.25
Total WLCC (₦)	40,762,489.34	51,381,675.13	76,404,736.09
WLCC PER GFA	37,743.05	47,575.63	70,745.13

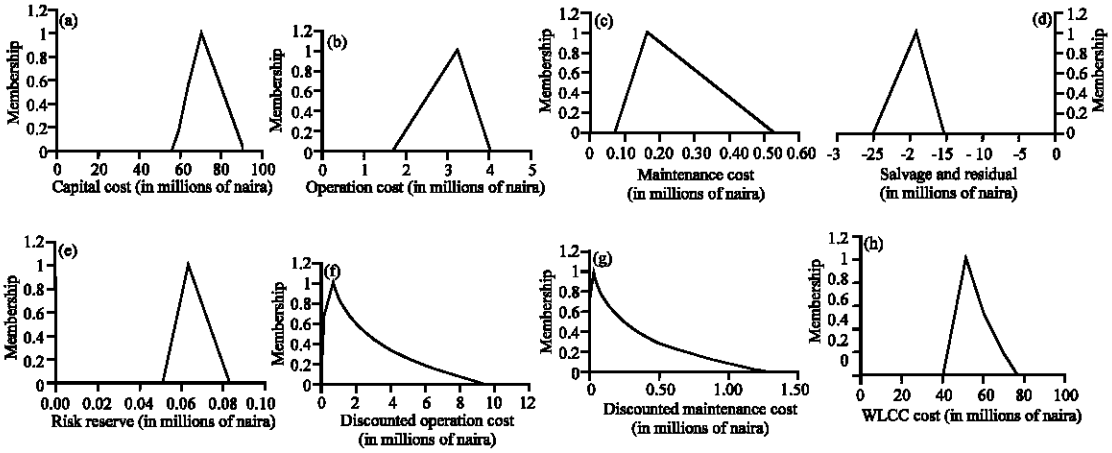

Fig. 6: Membership functions for the various cost categories, risk reserves, discounted operations and maintenance costs and WLCC

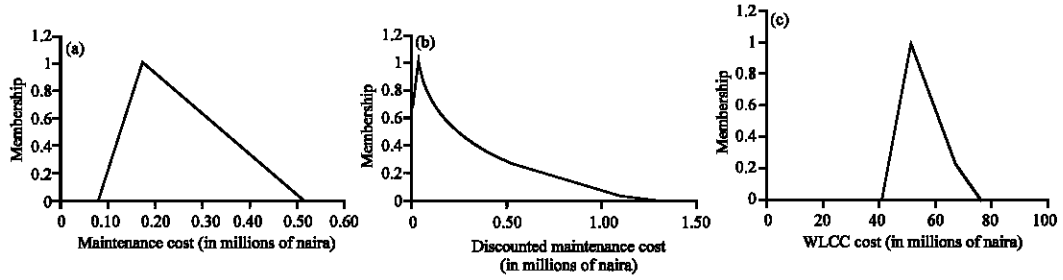

Fig. 7: Membership functions for undiscounted and discounted maintenance cost and WLCC

Table 12: Range of values for the various economic data and cost categories at different data reliabilities

Item description	Reliability value	Minimum value	Maximumvalue
Inflation rate (%)	0.75	3.76	4.26
Borrowing rate (%)	0.90	21.80	22.30
Analysis period(Years)	0.75	38	42.50
Discount rate (%)		3.34	3.89
Future worth factor (A)		3.42	5.07
Present Worth of Annuity factor (FWA)		0.12	0.36
Capital cost	0.70	65,797,438.64	76,101,459.52
Finance cost per annum		0.00	0.00
Operation cost per annum	0.70	342,276.74	1,235,544.55
Maintenance cost per annum	0.70	17,689.96	96,910.54
Sundries		0.00	0.00
Salvage and residuals	0.50	-17,405,416.15	-22,172,265.80
Risk reserves	0.70	60,075.35	69,400.79
Total WLCC (₦)		48,812,064.54	55,331,049.61
WLCC PER GFA		45,196.36	51,232.45

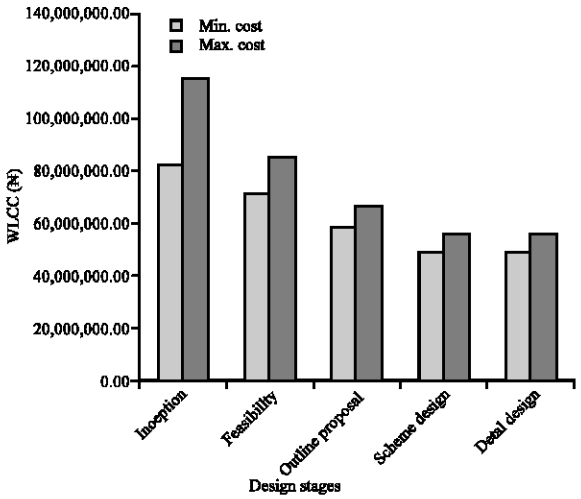

Fig. 8: WLCC at various design stages

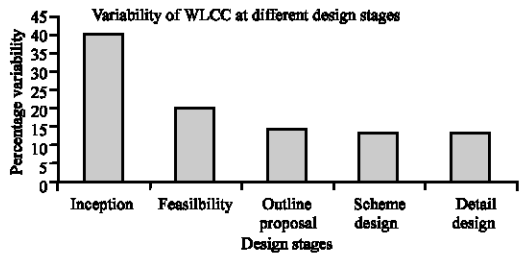

Fig. 9: Variability of WLCC at various design stages

stage to about 13% at the detail design stage. This is logical since uncertainty is reduced as design information becomes available. Furthermore, it should be noted that the ability to influence cost is greatest at the early design stages as could be seen when the costs at the outline proposal stage are for instance, compared with the costs at the Inception and Detail design stages. This phenomenon is in conformity with the assertions made by Boussabaine and Kirkham (2004) and Flanagan and Jewell (2005).

CONCLUSION

The algorithm proposed in the first series to this paper was used in the preparation of WLCC plan at the different stages of design evolution. A comparison of the results obtained at the different stages confirms previous assertions that both uncertainty and the ability to influence cost decreases as the design passes from inception to detail design stage.

The main advantage of the algorithm is that, the quantity of data required to implement it is minimal and readily available, which reduces the cost of data collection and analysis, thereby, improving the usability of WLCC, especially in the developing countries. Another important advantage of the algorithm is that it expresses variables as 3 point data which represents the minimum, likely and maximum values which is logical and convenient since samples of a specific data item under similar conditions should be expected to be distributed around the modal class. Other advantages of the algorithm are that it is computationally more efficient when compared with other techniques like Monte Carlo simulations and it allows the selection of different reliability values for different data items, which makes it flexible in terms of risk assessment and control.

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