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asasubmitpaper@gmail.com

Exploring Sensitivity Analysis as a Tool in the Financial Management of Construction Contracts

Robinson, Ariba Isaac[1] and Okeke, Clara Chinwe[2]
[1]Department of Quantity Surveying | GSM: 08039683168 | E-mail: airgoffoundation@yahoo.com
[2]Department of Accounting | GSM: 08037093731 | E-mail: okekeclara8@gmail.com
[1&2]Abia State Polytechnic Aba, Abia State, Nigeria

Abstract: *The study demonstrated the impact of changes in the price of a building material (50kg bag of cement) on the total estimated cost of a building construction project using sensitivity analysis and thereafter developed a financial sensitivity analysis model that will ascertain the effects of changes in prices of materials to overall cost of a building construction project. It provides consistent framework for consideration of values obtained from sensitivity analysis before embarking on a construction contract using the researchers' formulated question (example). The data used were sourced from an Umuahia based construction firm. Values obtained were analyzed using table, percentage and graph. The study found out that sensitivity analysis is a veritable tool for predicting the impacts of changes in the market prices of labour and materials on total cost of building construction contracts. Application of sensitivity analysis on construction contracts as a condition of contract; and establishment of ceiling point for values obtained from sensitivity analysis were recommended.*

Keywords: *construction contracts, finance, input, output, sensitivity analysis*

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INTRODUCTION

Sensitivity analysis also known as "what if" or simulation analysis is a financial tool used to determine effects of different values of an independent variable on a particular dependent variable under a given set of reasonable assumptions. *Hawks (2018) defines sensitivity analysis as* a data-driven investigation of how certain variables impact a single, independent variable and how much changes in those variables will change the independent variable. Fekete Associates Inc. (2012) defined sensitivity analysis as the systematic investigation of the outcome of outputs to extreme values of the inputs of a model.

Investopedia (2018) stated that sensitivity analysis is used within specific boundaries that depend on one or more input variables, such as the effect that changes in interest rates (independent variable) has on bond prices (dependent variable). EduPristine (2018) stated that

the usage of sensitivity analysis works on the simple principle: - change the model and observe the behaviour. Pannell (2017) described sensitivity analysis as the investigation of potential changes and errors and their impacts on conclusions to be drawn from a model. According to him, sensitivity analysis can be easy to do, understand and communicate and that it is mostly used by modellers who intends to support decision makers.

A careful study of Unlimited Consulting and Auditing Partnership (2018) reveals that the environment of a business is very unstable, and it can change quickly due to the influence of external factors. She stated that these external factors can be anything from the change in a sales demand to the new application of a government policy that is not in the favour of business and can result in the decrease in patronage by customers and maybe increase in costs. This will invariably reduce the profits of the company. To prevent this from happening, the companies need to monitor the external environment continuously.

By keeping track of the changes in the external factors, necessary actions can be taken to prevent the losses. In order to keep track of the external changes, the entity needs to implement a method that will help it determine the sensitivity of its appeal to clients, costs and changes in its income patterns. The sensitivity analysis determines the changes in the quantifiable variables of construction contracts to determine its viability.

Given the above, the study seeks to:

1. Demonstrate the impact of changes in the price of a building material (50kg bag of cement) on the total estimated cost of a building construction project using sensitivity analysis.
2. Develop a financial sensitivity analysis model that will ascertain the effects of changes in prices of materials to overall cost of a building construction project

THEORETICAL FRAMEWORK

CFI Education Inc (2018) stated that Sensitivity Analysis is a tool used in financial modeling to analyze how the different values of a set of independent variables affect a specific dependent variable under certain specific conditions. Pannell (2017) stated that the process of conducting a sensitivity analysis in order to choose an optimal strategy can proceed by following an initial run with a model that incorporates best-bet values which are anchored on probability distributions. He also stated that the distribution are likely to be less uncertain due to the information obtained from sensitivity analysis; and that sensitivity analysis lays so much emphasis on changing and observing the models to meet organizational objectives. Iooss & Saltelli (2019) stated that sensitivity analysis provides users of models that are based on mathematics and simulation models with tools to appreciate the dependency of the output from input of the models which is aimed at investigating how important the models are to each other. Fekete Associates Inc. (2012) stated that once outputs and inputs of sensitivity analysis are determined, the obtained data can be displayed using a tornado plot or a spider plot. By tornado plot, she meant a vertically stacked bar chart that displays the range of an investigated outputs and are sorted based on their strength. By spider plot, she meant that the magnitude of the output range affected by each input must be determined before any other thing.

In general, Sensitivity Analysis is used in a wide range of fields, ranging from biology and geography to economics and engineering. Financial Sensitivity Analysis is done within defined boundaries that are determined by the set of independent (input) variables. For example, Sensitivity Analysis can be used to study the effect of a change in interest rates on prices of financial instruments if the interest rates increased by 1%. In the above instance, sensitivity analysis would provide answer to the question - **"What** would happen to the prices of the

financial instruments **if** interest rates went up by 1%?" The analysis is performed in Excel under the Data section of the ribbon and the "What-if Analysis" button, which contains Goal Seek and Data Table.

Sensitivity Analysis is used to understand the effect of a set of independent variables on some dependent variable under certain specific conditions. For example, if a financial analyst wants to find out the effects of a company's net working capital on its profit margin, the analysis will involve all the variables that have an impact on the company's profit margin such as the cost of goods sold, workers' wages and managers' wages, etc. The analysis will isolate each of these fixed and variable costs and record all the possible outcomes.

The Purpose of Sensitivity Analysis

Unlimited Consulting and Auditing Partnership (2018) stated that in a sensitivity analysis, only the unfavorable changes are accounted for to consider the impact of these changes on the profitability of the contract. She also stated that sensitivity analysis serves following purposes:

1. Helps in identifying key variables that are of major influence in the cost and benefits of the contract. Demands, expenses, operating costs and legal costs, revenues and financial benefits are included in this stage.
2. Helps in determining the consequences of the unpleasant amends in these key variables.
3. Helps entities to assess whether these changes will affect the contract on project decisions made.
4. Helps in identifying and implementing the actions that will help mitigate these adverse effects.

Performance of Sensitivity Analysis

Sensitivity analysis is a powerful tool for examining issues relating to uncertainties in model structure, or in input or parameter values. Inputs may be defined as the proposed values of any parameter or state variable whose true value is uncertain. The objective of sensitivity analysis is three-fold namely:

1. To estimate the uncertainty in the model's predictions caused by uncertainty in the values of inputs
2. To examine the consequences of varying the model's structure on its generality and predictive power.
3. To determine the degree to which inaccuracies in their assumed values could lead to serious errors in prediction.

Sensitivity analysis is the fundamental step before calibration when considering all the parameters. Jorgensen (1994) in *Ray & Mandal (2015)* stated Sensitivity analysis attempts to provide a measure of the sensitivity of either parameters, or forcing functions, or sub-models to the state variables of greatest interest in the model. Sensitivity analysis is performed using the following formula:

$S = (dx/x)/(dp/p)$

where S = sensitivity, x = state variable, P = parameter, dx and dp are change of values of state variables, parameters, and forcing functions, respectively, at ± 10% level in temporal scale.

Those parameters, which are almost impossible to determine from the field are calibrated using a range of values (minimum to maximum) from the literature first and further the appropriate value for that parameter for this estuary is determined according to the best fit of the value during the model run by using standard calibration procedure (Jorgensen, 1994 in *Ray & Mandal 2015).*

In order to optimize the utility of the sensitivity analysis, it needs to be carried out in a systematic manner. To optimize the performance, entities can follow following steps:

1. Identification of the sensitive variables which affect the construction contract decision
2. Calculation of the effects of these changes
3. Consideration of the variables in possible combinations that can be changed simultaneously

Uses of Sensitivity Analysis

Sensitivity analysis:

1. helps the financial expert to properly assess risk and understand advantages and disadvantages of a decision model
2. indicates the sensitivity of simulation to uncertainties in the input of the model
3. helps in decision making by predicting the outcome of a decision
4. makes recommendations more credible, understandable and persuasive
5. detects errors that have cost implications
6. provides appropriate insight into the problems and solutions associated with the model under reference

METHODOLOGY

Secondary data collected from the bill of quantities, market survey and cost index of an Umuahia based construction firm, AIRGOF KONZORLT. The data were analyzed using tables, graphs and percentage. From the data collected, a question which serves as an example was used to demonstrate the impacts of sensitivity analysis in the financial management of construction contracts. The example (question) is:

"In 2012, the price of a 50kg bag of cement was ₦2,500.00 only. Based on the price, the estimated building construction contract cost of sub-structural quantities was ₦11,549,163.99. In 2013 and 2014, the prices of a 50kg bag of cement were ₦2,700.00 and ₦2,850.00 respectively. Analyze sensitively the effects of changes in the price of a 50kg bag of cement on the estimated building construction project costs for 2016 and 2017 using the Bill of Quantities below which was prepared in 2015."

Additional Information:

1. 28nr of 50kg bags of Cement ≡ 1m3
2. The emphasis is on cement. Thus, every other thing remains constant.
3. Cost of Items Affected by Price of Cement = CIAPC
4. Sensitivity Analysis = SA, Δ = Change, C = Price of Cement and Building construction project Cost = PC
5. Output is the building construction project cost while input is the price of cement.
6. With 5% profit margin (mark up), the organization's ceiling for sensitivity analysis is 2% that 0.02. This means that once sensitivity analysis is above 0.02, the organization will not go with the building construction project till there is a review in price.

RESULTS, ANALYSIS AND DISCUSSION

The Question – *"In 2012, the price of a 50kg bag of cement was ₦2,500.00 only. Based on the price, the estimated building construction project cost of sub-structural quantities was ₦11,549,163.99. In 2013 and 2014, the prices of a 50kg bag of cement were ₦2,700.00 and ₦2,850.00 respectively. Analyze sensitively the effects of changes in the price of a 50kg bag of*

cement on the estimated building construction project costs for 2016 and 2017 using the Bill of Quantities below which was prepared in 2015."

Additional Information:

1. *28nr of 50kg bags of Cement ≡ 1m3*
2. *The emphasis is on cement. Thus, every other thing remains constant.*
3. *Cost of Items Affected by Price of Cement = CIAPC*
4. *Sensitivity Analysis = SA, Δ = Change, C = Price of Cement and Building construction project Cost = PC*
5. *Output is the building construction project cost while input is the price of cement.*
6. *With 5% profit margin (mark up), the organization's ceiling for sensitivity analysis is 2% that 0.02. This means that once sensitivity analysis is above 0.02, the organization will not go with the building construction project till there is a review in price."* was solved and used to demonstrate the impacts of sensitivity analysis in the financial management of building construction projects as follows:

Notes: Building construction project Cost = PC, Amount = A, Amount, Quantity = Q, Unit Rate = UR and SA = Sensitivity Analysis, %Δ = Percentage Change

Workings

2012 ₦

C – ₦2,500.00

CIAPC = 7,559,127.14

PC = 11,549,163.99

2013

P – ₦2,700.00

CIAPC = 7,865,789.91

Less 2012 CIAPC = (7,559,127.14)

Add 2012 PC = 11,549,163.99

PC = 11,855,826.76

%Δ in C = ((2013C – 2012C)/2012C) x 100

= (2700 – 2500)/2500 x 100

= (200/2500) x 100

= 0.08 x 100

= 8%

%Δ in PC = ((2013PC – 2012PC)/2012PC) x 100

= (11,855,826.76 – 11,549,163.99)/11,549,163.99) x 100

= (306,662.77/11,855,826.76) x 100

= 0.02655 x 100

= 2.66%

An 8% increase in the price of cement will lead to 2.65% increase in the building construction project cost.

SA = %Δ in output/%Δ in input

= %Δ in PC/%Δ in C

= 2.66/8

= 0.33

0.33 is above the organization's ceiling for sensitivity analysis. Thus, there should be review.

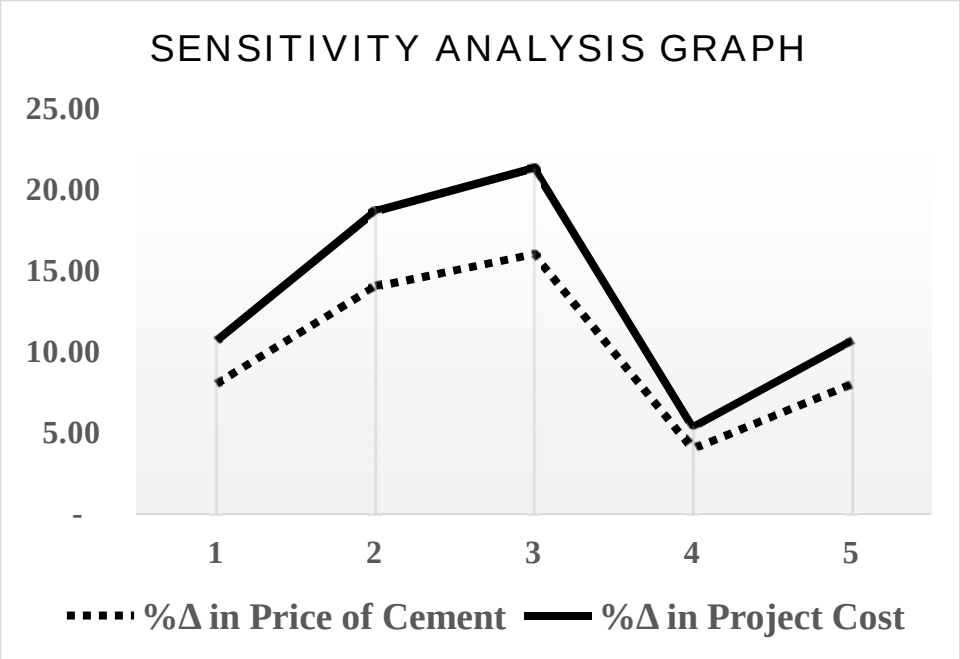
2014
P – ₦2,850.00
CIAPC = 8,095,796.41
Less 2013 CIAPC = (7,865,789.91)
Add 2013 PC = 11,855,826.76
PC = 12,085,833.26

%Δ in C = ((2014C – 2012C)/2012C) x 100
= (2850 – 2500)/2500 x 100
= (350/2500) x 100
= 0.14 x 100
= 14%
%Δ in PC = ((2014PC – 2012PC)/2012PC) x 100
= (12,085,833.26 – 11,549,163.99)/11,549,163.99) x 100
= (536,669.27/11,549,163.99) x 100
= 0.0465 x 100
= 4.65%
A 14% increase in the price of cement will lead to 4.53% increase in the building construction project cost.
SA = %Δ in output/%Δ in input
= %Δ in PC/%Δ in C
= 4.65/8
= 0.58
0.57 is above the organization's ceiling for sensitivity analysis. Thus, there should be review.
Let us plot a sensitivity analysis graph with additional increments in the price of cement as tabulated below.

Table 1.01 Showing the Impact of Changes in the Prices of Cement on Building construction project Cost

Year	Price of Cement	Building construction project Cost	%Δ in Price of Cement	%Δ in Building construction project Cost	Sensitivity Analysis
2012	2,500.00	11,549,163.99	-	-	-
2013	2,700.00	11,855,826.76	8.00	2.66	0.33
2014	2,850.00	12,085,833.26	14.00	4.65	0.58
2015	2,900.00	12,162,498.61	16.00	5.31	0.66
2016	2,600.00	11,702,495.34	4.00	1.33	0.17
2017	2,700.00	11,855,826.76	8.00	2.66	0.33

Note: Output is the building construction project cost while input is the unit rate.
Result: 8%, 14%, 16% and 4% changes in the price of cement will lead to 2.66%, 4.65%, 5.31% and 1.33 changes in the building construction project cost.



CONCLUSION

It is very clear that sensitivity analysis can help in the financial management of construction contracts. The only way to benefit from this tool is to get financial experts involved from the inception of a construction contract to its completion. This ensure construction project cost control and efficiency; cost minimization and wealth maximization. When this is properly done, the organization will not embarked on any construction project without being reasonably and predictably certain of effects of changes in the prices of labour, materials and the like.

RECOMMENDATIONS

Based on the impacts of sensitivity analysis on the financial management of construction contracts as shown in this study, the following recommendations are made:

1. Periodic application of sensitivity analysis on construction contracts in the event of price fluctuation should be part of conditions of contract.
2. Establishment of ceiling point for values obtained from sensitivity analysis. In other words, organizations should have tolerable values from sensitivity analysis so as to make timely decisions in the event of price change.

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PPENDIX ONE
UNIT RATES OF MASONRY AT CEMENT PRICE OF ₦2,500.00

	UNIT RATES										
Blkwk-m2	**4,687.03**	**Materials**	**Net**	**Voids**	**Waste**	**Mat.Total**	**Labour**	**Mark Up**	**Total**	**Cost/m2**
230mm thk filled solid -mortar 1:3	225				5%		1,023.75	5%	1,074.94	
Nr	9	Block	2,025.00		101.25	2,126.25		106.31	2,232.57	
Area of blk	0.91125	Loading	112.50		5.63	118.13		5.91	124.04	
Volume of blk.	0.20503125	Mortar	678.80			678.80		33.94	712.75	
Vol of mortar /ts	0.01996875	Filling	516.89			516.89		25.84	542.74	
Volume of filling	0.18251562	Total	3,333.19			3,440.07		172.00	**4,687.03**	
DPC - m3	**39,377.22**	**Materials**	**Net**	**Voids**	**Waste**	**Mat.Total**	**Labour**	**Mark Up**	**Cost/m2**	
Thkness	1000				5%		1,809.21	5%	1,899.67	
Vol of mortar -1:3	1	Mortar	33,993.23		1,699.66	35,692.89		1,784.64	37,477.54	
Labour output	26.31578947	Total							**39,377.21**	
DPC - m2	**1,571.81**	**Materials**	**Net**	**Voids**	**Waste**	**Mat.Total**	**Labour**	**Mark Up**	**Cost/m2**	
Thkness	38				5%		140.63	5%	147.66	
Vol of mortar -1:3	0.038	Mortar	1,291.74		64.59	1,356.33		67.82	1,424.15	
		Total							**1,571.80**	

	UNIT RATES										
Concrete - 1:4:8	24,771.08	Materials	Net	Voids	Waste	Mat.Total	Labour	Mark Up	Total	Cost/m3	
				40%	5%		**29,223.60**	5%	30,684.78	2,360.37	
	1	28 Cement	70,000.00	28,000.00	4,900.00	**102,900.00**		5,145.00	108,045.00	8,311.16	
	1	28 Loading	-1,120.00	448.00	78.40	**1,646.40**		82.32	1,728.72	132.98	
	4	3.81 Sand	16,797.90	6,719.16	1,175.85	**24,692.91**		1,234.65	25,927.56	1,994.43	
	8	3.81 Gravel	83,989.50	33,595.80	5,879.27	**123,464.57**		6,173.23	129,637.80	9,972.14	
	15	m3 Total	17,907.40	68,762.96	12,033.52	**252,703.88**		12,635.19	265,339.07	**22,771.08**	
Concrete - 1:3:6	25,713.27	Materials	Net	Voids	Waste	Mat.Total	Labour	Mark Up	Total	Cost/m3	
				40%	5%		**29,223.60**	5%	30,684.78	3,068.48	
	1	28 Cement	70,000.00	28,000.00	4,900.00	**102,900.00**		5,145.00	108,045.00	10,804.50	
	1	28 Loading	-1,120.00	448.00	78.40	**1,646.40**		82.32	1,728.72	172.88	
	3	3.81 Sand	12,598.43	5,039.37	883.89	**18,519.69**		925.98	19,445.67	1,944.57	
	6	3.81 Gravel	62,992.13	25,196.85	4,409.45	**92,598.43**		4,629.92	97,228.35	9,722.84	
	10	m3 Total	140,710.55	58,684.22	10,269.74	**215,664.51**		10,783.22	226,447.74	**25,713.27**	
Concrete - 1:2:4	31,177.32	Materials	Net	Voids	Waste	Mat.Total	Labour	Mark Up	Total	Cost/m3	
	M3			40%	5%		**29,223.60**	5%	30,684.78	4,383.54	
	1	28 Cement	70,000.00	28,000.00	4,900.00	**102,900.00**		5,145.00	108,045.00	15,435.00	
	1	28 Loading	-1,120.00	448.00	78.40	**1,646.40**		82.32	1,728.72	246.96	
	2	3.81 Sand	8,398.95	3,359.58	587.93	**12,346.46**		617.32	12,963.78	1,851.97	
	4	3.81 Gravel	41,994.75	16,797.90	2,939.63	**61,732.28**		3,086.61	64,818.90	9,259.85	
	7	m3 Total	119,473.70	48,605.48	8,505.96	**178,625.14**		8,931.26	187,556.40	**31,177.32**	

APPENDIX TWO
EXTRACT OF THE BILL OF QUANTITIES PREPARED IN 2016 AT CEMENT PRICE OF ₦2,700.00

S/N	Description	Qty	Unit	Rate (Naira)	Amount (Naira)
	SUBSTRUCTURE (PROVISIONAL)				
1.11	**INSITU CONCRETE WORKS**				
	Mass Concrete				
a.	Plain concrete (1:4:8 – 20mm aggregate) blinding; poured on or against earth; thickness not exceeding 300mm.	7	m3	23,435.97	164,051.79
b.	Ditto; (1:3:6 – 38mm aggregate) foundation footing.	31	m3	26,577.63	823,906.53
c.	Ditto; steps	4	m3	26,577.63	106,310.52
d.	Ditto; ramp	6	m3	26,577.63	159,465.78
	Horinzontal Work				
e.	Reinforced concrete (1:2:4 – 19mm aggregate) in column bases; well packed around reinforcement in formwork (both measured separately) and poured on against earth; thickness not exceeding 300mm thick	26	m3	32,412.12	842,715.12
f.	Ditto; floor slab	101	m3	32,412.12	3,273,624.12
	Vertical Work				
g	Reinforced concrete (1:2:4 – 19mm aggregate) in columns; well packed around reinforcement in formwork (both measured separately) and poured on against earth; thickness not exceeding 300mm thick.	5	m3	32,412.12	162,060.60
1.14	**MASONRY**				
h.	225mm thick hollow sand-crete strecther bond block work in cement and sand (1:3) mortar filled solid with concrete (1:10 all-in-aggregate)	454	m2	4,904.15	2,226,484.10
	Accessories/Sundry Items for Block Walling				
	Damp Proofing				
j.	38mm thick cement and sand (1:3) Damp Proof Course (DPC); not exceeding 225mm wide	65	m2	1,648.79	107,171.35
	COST OF ITEMS AFFECTED BY PRICE OF CEMENT				**7,865,789.91**

APPENDIX THREE
EXTRACT OF THE BILL OF QUANTITIES PREPARED IN 2016 AT CEMENT PRICE OF ₦2,850.00

S/N	Description	Qty	Unit	Rate (Naira)	Amount (Naira)
	SUBSTRUCTURE (PROVISIONAL)				
1.11	**INSITU CONCRETE WORKS**				
	Mass Concrete				
a.	Plain concrete (1:4:8 – 20mm aggregate) blinding; poured on or against earth; thickness not exceeding 300mm.	7	m3	23,934.64	167,542.48
b.	Ditto; (1:3:6 – 38mm aggregate) foundation footing.	31	m3	27,225.90	844,002.90
c.	Ditto; steps	4	m3	27,225.90	108,903.60
d.	Ditto; ramp	6	m3	27,225.90	163,355.40
	Horinzontal Work				
e.	Reinforced concrete (1:2:4 – 19mm aggregate) in column bases; well packed around reinforcement in formwork (both measured separately) and poured on against earth; thickness not exceeding 300mm thick	26	m3	33,338.22	866,793.72
f.	Ditto; floor slab	101	m3	33,338.22	3,367,160.22
	Vertical Work				
g	Reinforced concrete (1:2:4 – 19mm aggregate) in columns; well packed around reinforcement in formwork (both measured separately) and poured on against earth; thickness not exceeding 300mm thick.	5	m3	33,338.22	166,691.10
1.14	**MASONRY**				
h.	225mm thick hollow sand-crete strecther bond block work in cement and sand (1:3) mortar filled solid with concrete (1:10 all-in-aggregate)	454	m2	5,067.01	2,300,422.54
	Accessories/Sundry Items for Block Walling				
	Damp Proofing				
j.	38mm thick cement and sand (1:3) Damp Proof Course (DPC); not exceeding 225mm wide	65	m2	1,706.53	110,924.45
	COST OF ITEMS AFFECTED BY PRICE OF CEMENT				**8,095,796.41**