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Title: Causal relationship between material cost fluctuation and project's outturn costs

Abstract

Purpose
A section of project management literature attributes overruns to estimators' deceit and delusion. An example of this is Flyvbjerg's theorization of strategic misrepresentation and optimism bias. To show that such a notion is not true entirely, the study elicits evidence relating to how costs of projects often fluctuate erratically as prices of construction materials change throughout contract cycle times. The purpose of the study is to examine the causal relationships between persistent changes in prices of construction materials and project's outturn costs.

Research Design
We obtained and analysed price data of construction materials published in a Nigerian national daily in the 16 years between 2000 and 2015. Additional data were obtained from a quantity surveying firm to validate the archival data on material prices, and to compare the firm's robust database of project estimates and the corresponding outturn costs of specific building elements (detailed in the study). The goal of the analysis is to explore spontaneity and causal impact in the relationship between changes in prices of construction materials and project costs. Kolmogorov-Smirnov and Anderson-Darling tests were used to obtain the probability distributions of the causal relationships.

Findings

Findings show disproportionate positive correlations between changes in material prices and outturn costs in Nigeria. An important dimension to this however is that although fluctuations in material costs often trigger variations to project costs, outturn price only accounts for about one-third of actual cost variabilities. Recovery of costs, not least profit making, under these conditions is a complex process.

Value

We conclude that dynamism in cost attributes is neither a deceit nor a delusion; understanding and tolerating them is not a systemic weakness, rather an essential key to project success and stakeholder satisfaction. Findings from the study also bring measured certainties to the transformation of variable costs into fixed price outcomes, an important consideration that will help contract estimators and project managers to understand the likelihood of fluctuation in material costs and how these might trigger variabilities in project costs.

Keywords: construction project management, contract administration, cost variability, Nigeria, outturn cost, price fluctuation.

Introduction

Normative literature portrays project completion within pre-contract budget as a vital indicator of success (Ansar *et al.,* 2014; Pinto and Mantel, 1990). However, the construction industry has had a rich history of not completing projects within budget. Ahiaga-Dagbui *et al.* (2015:865) describe this as a recurrent problem that researchers have struggled to unravelled appropriately. The authors argue there is no shortage of knowledge regarding *why* project estimates vary from actual costs. However, ideas are scant regarding *how* change agents metamorphose into *chaotic* outcomes in construction project costs. This critical knowledge gap in this is in connecting the *why* to *how* causations explain *chaotic* outcomes construction project cost management. Without this, estimators are unlikely to exercise accurate judgements in predicting and mitigating cost variability, either whilst developing estimates or when managing contracts. As Cantarelli *et al.* (2012) surmised this as a leading cause of inaccuracy in estimating processes.

Estimators often predict the cost implications of resources needed to complete a project. Materials are a vital aspect of this. According to Omange and Udegbe (2000), construction materials account for up to 60 percent of project costs. Rowse (2009) agrees also that costs of construction materials have enormous effects on project costs. Rowse's study shows that increases in the costs of vital construction materials are rampant, and have become onerous to predict. Elinwa and Buba (1993) conclude that fluctuations in material costs are a major cause of rise in costs of construction globally. One overarching challenge in this is that materials used for construction are diverse, and of varying sizes. As a result, they pose economic issues in multiple dimensions. When material prices change irregularly, their influence on outturn costs can become noticeable in outturn costs spontaneously.

Many causality theorists often use probability theories to characterise causations by focusing on probable relationships between cause and effects (Greenland, 2011; Pearl, 2009). Love *et al.* (2012) have explained the application of this to construction cost management. They determined the likelihood of overruns occurring by using probability theory. However, how causations transform into overruns were not included in the analysis. Another work by Love et al. (2016a) argues that probability theory is an appropriate way to go in examining the relationship between fluctuation of materials prices and variability in project costs. The purpose of this study is to build on Love *et al.*'s works by using empirical data to identify the causal relationships between fluctuation of materials prices and project's outturn cost. One objective of the study is to determine the rate of change and likelihoods of prices changes in select critical construction materials. The second objective is to investigate the impact of price changes on project's outturn cost.

Causality of cost variability

Construction management literature is replete with information regarding reasons why project estimates vary from actual costs. Love and Smith (2016) identify such causes to include design errors and rework. Flyvbjerg (2008) and Cattell et al. (2010) think estimates differ from outturn costs because estimators are deceptive, delusional or are overly optimistic about uncertain situations that may come up when projects get underway. Baccarini's (2005) opinion is different. The author underlines design and construction contingencies as another cause of variation in project costs. Huang *et al.* (2013) and Love *et al.* (2008) have added more dimensions to these, in the nature of clients' soft requirements and contractor's capacity to bifurcate [i.e innovate and create impromptu solutions during construction such that outturn situation of a project could satisfy clients further].

Not least important, Olatunji (2010), Baloi and Price (2003), and Akintoye (2000) outline the impact of macro-economic factors on pre-contract estimates, and how these transform into a rise in outturn costs. Such factors include inflation [industry-specific cyclical inflation and general changes in price levels of commodities in the whole economy], interest rates [and costs of finance], foreign exhange rates, taxation, balance of trade, economic health of the construction sector, overall health of the economy and rate of resource employment. In addition, the works of Skitmore *et al.*, in particular in Skitmore *et al.* (2007), Skitmore and Smyth (2009) Skitmore and Picken (2000), and Skitmore and Patchell (1990), to mention a few, are quite illuminating. The authors argue eloquently on how estimators often strive to capture the psychology of the bidding environments by projecting their estimates with the immediate intention to win rather than reflecting actual costs when projects gets underway.

The implications of these study is such that construction estimating is not an ideal linear process. In particular, as often the case, if project costs are unpredictable by a linear relationship between resource inputs (such as labour, materials, plant and mark-up) and a stable rate of change in time value of money, the outcome is such that actual costs of projects will remain unknown until a time after practical completion. Many studies portray cost as a unitary element with a constant rate of change as though all the many inputs that go into construction have a single rate of change over time, in all locations, and in the same manner as the rate of change in other sectors of the economy. Example of these include Paasche model, Laspeyres model and Fisher's model - see Balk (2010), Fleming and Tysoe (1991) and Seeley (1972).

Other studies have built relative alternatives to these through time series analysis modelling. For instance, Ashuri and Lu (2010) used seasonal Autoregressive Integrated Moving Average (ARIMA) and Holt–Winters exponential-smoothing to model construction cost index through the average monthly prices of construction activities in the form of time series analysis. Moon and Shin (2017) also modelled how construction costs behave when an economy fluctuates, in a similar manner to Ashuri and Lu's. The centrality of these approaches is that the authors seem to assume that there is considerable certainty in how construction activities relate with economic indicators over time. In developing countries where economic indices are largely precarious, and the randomness of cost behaviours of construction input is overly chaotic, these linear models have only a limited chance of success. In addition, as pointed out in the works of Baccarini, Flyvbjerg, Love, Olatunji and Skitmore, amoral business behaviours also complicate the dynamism of construction costs, in that they are best studied as a characteristic system rather than a linear process.

System thinking

There is considerable material evidence in these extant studies to conclude that estimating science may only be an art rather than a definitive science. This is because, as the reviewed studies elicited, project estimates are not designed to reflect actual costs always. Studying the usual dichotomy observed between the two is a complex science (e.g. see Winch, 2010). Many authors have used various perspectives of system dynamics to provide scientific explanations to the phenomenon of cost variability [i.e. the ability of outturn costs to vary from pre-contract estimates]. A consensus that is evident in literature is that cost variability is a complex phenomenon. A study on causations of cost variability should consider the change trends in cost dynamism as a system issue i.e. looking into interdepencies between the system's components rather than isolating each individual part (Cabrera *et al.,* 2008; Checkland, 1999). Olaniran *et al.* (2017) noted this as the main difference between system thinking and traditional approaches in project management: the latter concentrates on individual components of a system, while the former focuses on interactions between and within constituent subsystems to trigger unique outcomes in outturn situations. By considering a bigger picture of outturn situation of a system, observable variations in the subsystems do not necessarily explain a system's outturn situation.

Practical implications of using system thinking to explain cost variabilities can be simplified. Cost management of construction projects is often shaped by interactions within project controls [i.e. resourcing, contracts, technologies and commitment to accountability]. In addition, it is important to consider how these are impacted by intrinsic variabilities within [i.e. multi-directional interconnectedness of] a project's own sub-systems. External variables trigger changes to outturn costs also. In essence, system thinking helps to understand the interdependencies in how intrinsic and external components interact to transmit and return effects that they generate within a system and the resultant outcomes on the overall system (see Hung, 2008). For example, many studies have identified varying degrees of cost variability in construction projects. These include Odeck (2004) who analysed 420 samples of road projects and found 7.9% average overruns, which ranged from 59 – 183%. Flyvbjerg *et al.* (2003) also found 50 – 100% overruns in 9 out of 10 projects he analysed, whilst Cantarelli *et al.* (2012) examined 29 road, 28 rail and 30 fixed link projects and found an average of 10.3% overruns overall but 18.5% in road projects only. Love *et al.* (2012) studies 58 transport infrastructure projects in Australia, and found the average cost overrun as 13.8%.

Systemicity of cost variability is a question of identifying and understanding *why* and *how* estimates vary from outturn costs (Checkland, 1999). Without these, it is onerous to manage and mitigate issues around causalities and causations of variabilities. Causes of cost variability are well reported in literature. However, there are only limited reports on how they occur and multiply in momentum as projects progress. For example, in a study involving 161 projects, Le-Hoai *et al.* (2008) identify thematic causes of cost overruns to include scope variations, delays and the tendency amongst various players to mislead as well as resourcing issues. None of these causes is cast-in-stone. Causatives can occur without hurting project budget. Aje *et al.* (2017) presented some project samples where delays in completion and scope variation did not influence pre-contract estimates. Ali and Kamaruzzaman (2010) conclude most estimates vary from outturn costs because of wrongful application of estimation methods that often lead to poor outcomes. The work of Daniel and Anny (1988) adds some depth to these also. The authors found that delays and cost variabilities can occur orthogonally, and that incessant fluctuation in prices of construction resources is a critical challenge of project success. Bromilow's (1981) model adds price indexing, relative to inflation rate, as a dimension to this. By applying Checkland's (1999) model on systemicity to how cost variability occurs, it is possible to draw a big-picture scenario that is convenient for an objective analysis regarding how the cost of numerous resources used for construction vary erratically, with or without recourse to coalesced inflation rates.

Probability theory of causation

Causation theorists have used probability theory to explain the causal relationships between two events (Gopnik and Wellman, 2012; Greenland, 2011). The theory suggests one event may cause a change in another event if there is probabilistic association in the relationship between the two events. For example, if outturn costs are built on cost of construction resources, there should be a considerable association in the probability that the latter can trigger changes in the former, and not vice versa. Probability theory of causation helps to understand the likelihood that changes in prices of construction resources will affect outturn costs of projects, and by how much.

There could be several causations to how phenomena evolve in a systemicity, and the entropies effected by these are not least simplistic. Interdependencies between causations and the effects they create are quite complicated: between individual causations, and/or between groups of causations, likewise between effects as generated by noticeable causations, and as the generated effects further transform into causations that can generate further effects. Nonetheless, according to Love and Smith (2016), probabilistic causation theory can be used to forecast the occurrence of cost variability by considering price fluctuation as a main cause.

Research Methodology

Some research philosophies have been deployed to study causal dependencies between multiple variables. Some of these fit well into the aim of this study, which is to determine whether and how erratic changes in the prices of construction materials influence outturn costs of projects. Typically, most researchers find it convenient to study change using historical data. However, when change trend becomes chaotic i.e. variables (e.g. construction materials) are multifarious, and with erratic interdependencies, it is practically impossible to predict outcomes accurately by relying on historical data only. This is because no two projects are identical absolutely. Even where resources and productivity are the same, indirect and unrelated events as well as stakeholders' motivation to succeed have often influenced costs differently. While it is popular amongst researchers to predict change propensity by considering resource costs only or outturn costs only, the practicality of research outcomes from these approaches have suffered. The reality of cost performance problems is such that these dimensions only explain causations of variability partially. For example, changes in prices of resources do not automatically lead to change in contract prices. If clients are not contractually obliged to consider every erratic movement in resource prices, what then in the relationship between erratic movements in price levels and what is the predictive capacity of such relationship?

The approach taken in this study is to concentrate on basic materials used frequently for construction works across different trades. Examples of such include cement, aggregates and reinforcement used for concrete, walls, finishes and external works. As these items are used frequently, it is possible to figure out the impact of changes in their respective prices on outturn costs. It is also possible to find out how such changes impact the unit rates of work in the respective trades where they feature. For example, if cement and aggregates have the most erratic changes in cost and contribute the most significant volume in concrete work, and their prices change by a particular amount over a period of time, how much will the unit price of concrete change? Another dimension to this, considering clients' tolerance of price volatility, is to examine outturn price that clients pay for actual fluctuations in the prices of construction materials.

Sample Frame

Five key components of building construction were considered for analysis. These are in-situ concrete, earthwork, masonry, roofing and reinforcement. Prices of materials used for the construction of these elements were studies. These include cement, fine aggregate, coarse aggregate, steel reinforcement bars, concrete block, laterite (earth-fill) and roofing sheet (aluminium, corrugated). Purposive sampling technique was used – this is often used when a selection of a small unit of the whole is built on the assumption that the selected small sample will offer same features as whole (see Neyman, 1934 and Kothari, 2004). Fluctuations in the prices of these materials were considered for the 64 quarters in the 16 years between 2000 and 2015. The data on this were collected from price databases, reported monthly in *the Guardian*, a prominent national newspaper in Nigeria. *Guardian*'s methodolody focuses on obtaining average retail prices of saundry construction materials from Nigeria's major metropolis. Data on outturn costs and basic rates were also collected from consultant quantity surveyors. These are historical data from their past projects, quarterly averages taken the same way as prices of materials.

These sources are appropriate for this study because majority of construction businesses in most developing countries are indigenous firm, mostly small in size; and they only source retailers. Differentiations have not been made for location issues e.g. logistics, storage and terrain; volume of trade, e.g. trade discounts, supply efficiecies; applications and methods e.g. complexities involved in actual applications of the materials; and contractors' proprietary rights e.g. whether they own or make some of the materials themselves. These exclusions help to simplify the data capture and analysis. Further adjustments could be made to findings from a basic analysis on a case-based basis such that unqiue cases can be accommodated adequately.

Results

Change in Prices

Evidence (see Table 1) suggests the prices of basic prices of construction materials in Nigeria have changed erratically every year. Cement, for example, rose in price by over 2.4% each year from 2000 to 2005, but plummeted by more than 3% annually between 2006 and 2015. Fine aggregate has seen more radical changes in prices: less than 3% rise annually from 2000 to 2005, and more than 10% increase every year between 2006 and 2015. In contrast, changes in the prices of coarse aggregate have been in the opposite direction; from close to 10% yearly rise between 2000 and 2005 to less than 8% between 2006 and 2010, and a gradual fall in price by nearly 1.5% yearly between 2011 and 2015. The cost of laterite earth fill also shows a downward trend, of nearly 8.5% cost reduction every year between 2000 and 2005, which reduced to just above 4% cost decline annually between 2006 and 2010, but a rise of close to 4.3% annually between 2011 and 2015. Bar reinforcement, 16mm diameter high yield bars in particular, was on a steep rise of more than 21% annually between 2000 and 2005 before the trend changed to just under 12% between 2006 and 2010 but flattens to less than 0.4% price increase between 2011 and 2015. Apparently, rise in the prices of concrete block shows little or no relationship between the trend of change in cement and fine aggregate, the main components of blocks. Blocks rose by more than 26% every year between 2000 and 2005 but plummeted by nearly 2% every year between 2006 and 2010 before rising by more than 2.5% between 2011 and 2015. Like steel reinforcement, corrugated aluminium roofing sheets also rose erratically every year. Between 2000 and 2005, the material rose by just under 17% annually; by just under 11% yearly between 2006 and 2010 and by close to 7% annually between 2011 and 2015.

Insert Table 1

Causal relationships

The change phenomenon in the prices of construction materials evidenced in Table 1 is frequent, persistent and random; suggesting an entropic situation, unpredictable and in a persistent slide into chaotic disorderliness. How do many items that change erratically combine into stable or fixed budget over a period of time in contract cycle times as clients may expect, and how do these interact and impact each other? Further analysis, Pearson's moment correlation, was undertaken to explore the causal relationships between prices of construction materials, the unit price when these items are estimated into a project budget, and the actual amount (outturn cost) paid for each unit item in which these items have been used (see Table 2). Findings show changes in the costs of cement and aggregates trigger significant changes to the budgets of all cement-based items (e.g. concrete, concrete blocks and block-walling), but not to actual amounts paid by clients for these items. A noticeable exception to this is where there are contractual variations to the budgets of these items (e.g. where pre-contract budgets have become invalid as a result of major changes to work scope or a significant fluctuation in resource prices acknowledged by client). For example, when the price of cement increases significantly, budget estimates and outturn costs of concrete items (e.g. in-situ concrete, retail prices of concrete blocks and block-walling) will increase automatically, mostly likely at a rate not defined by the change in the prices of cement, aggregate and blocks. When there are sporadic reductions in the prices of these items, budget items and outturn costs may remain unchanged.

Another key finding noted in the analysis is the strong correlation between steel products (e.g. bar reinforcement, roofing sheet), laterite and cement. Cement and steel products are largely imported products, susceptible to the fluidity of international market prices. Although these items are unrelated, not least laterite which is an abundant local material, rises in the costs of cement and steel products have often occurred simultaneously. Apparently, there is unifying factor in these unrelated but consistent change events e.g. foreign exchange and monetary policies. When local materials show spontaneous reactions to these (e.g. laterite and aggregates showing significant correlation with budget estimates of concrete and, budget estimates and outturn costs steel products). Apparently, they are also impacted by unique inflationary trends, perhaps seasonal pulls in demand and supply.

Insert table 2

A linear regression model was developed to explain the relationship between these episodic change events between construction material, budget estimates and outturn costs (see equation 1). Result shows [R = 0.724] 72.4% of outturn costs of concrete work is explained by prices of cement, fine and coarse aggregate, and budgeted rate of concrete work. The proportion of variability of independent variables explained in the model is 52.3% [$R^2 = 0.523$], while the adjusted R squared value, the degree of completeness of the model, is 49.1%.

$$Concrete_{(Otn)} = 3942.653 + 0.382Ce - 0.110FA + 0.970C\_rate - 0.085CA \quad \text{(Equation 1)}$$

Where $Concrete_{(Otn)}$= outturn concrete cost; Ce = bagged cement (50kg); FA = fine aggregate (5 tons); CA = contract rate for concrete, 25MPa; CA = coarse aggregate, 5 tons.

Significance of variance between groups of variables was also examined. At a significance level (p-value) less than 0.05, results show the contributions of the independent variables are not equal. 50% outturn cost of in-situ concrete is explained by changes in the price of cement, and that an increase in the price of cement above current prices may increase the outturn cost of in-situ concrete by 17.3%. However, a change in the prices of aggregate impacts outturn costs of in-situ concrete differently; an increase in price of fine and coarse aggregate will explain negative variations in outturn cost of concrete by up to 48% and 54% respectively.

Probability distribution fitting for material price fluctuations

Best fit probability distribution of the select construction materials used for the study was obtained using Kolmogorov-Smirnov and Anderson-Darling models (see Table 3). Probability density and cumulative distribution functions were obtained from this to predict the likelihood of fluctuation in price of the materials as well as the outturn costs (see Table 4). Analysis shows the probability of 15% increase above the yearly mean price of cement is 38% [(P(X>X1), 0.38)]. With a probability delimiter set at 95%, there is a 95% chance that a bag of cement, 50kg in weight, will increase to ₦2,400. The probability that the cost of fine aggregate will increase by 15% above yearly average is 31% [(P(X>X1), 0.31)], a 93% chance that price of 5 tons of fine aggregate will increasing to ₦23,000. For coarse aggregate, the probability that the price will rise by 15% increase above the yearly average is 35% [(P(X>X1), 0.35)], a 93% chance that the price of 5 tons of coarse aggregate will increase to ₦30,000. Similar outcomes were obtained for 225mm wide concrete blocks and 16mm diameter high yield reinforcement bars and reported in Figures 4 and 5 respectively. The probability that their prices will rise by 15% is 43% and 45% respectively. Analysis shows a 92% chance that the price of 225mm wide concrete blocks will increase to ₦160, and a 69% chance that a ton of 16mm diameter high yield reinforcement bars will rise to ₦160,000 after 2015.

Insert table 3

Insert table 4

Same procedure was repeated to predict fluctuations in outturn costs of line items in budgets also. Analysis shows a 19% probability that clients will pay 15% more than yearly average of pre-contract estimates for blockwork, and an 89% chance that building a unit of block wall area will increase to ₦3000. There is also a probability of 2% that clients will pay 10% more than yearly average of pre-contract estimates for 25MPa in-situ concrete [(P(X>X1), 0.02)], and a 98% chance that the unit price of the item will not exceed ₦30,000 after 2015. For 16mm diameter high yield reinforcement bars, analysis shows a 16% probability that outturn cost will rise by 10% above the yearly average [(P(X>X1), 0.16)], and a 90% chance that clients will only pay up to ₦250,000 for every ton of 16mm diameter high yield bars completed after 2015.

Discussion of Results

Numerous types of construction materials are used for construction, the prices of which change variously in a manner that is nearly impossible to predict. There are external dimensions to this too: random or chaotic behaviours of costs in construction projects are often impacted by other forms of variables such as plant and labour resources, planning and methods, and on-costs. All of these vary erratically also. In addition, Leslie's (2015) review of causations of overruns in megaprojects identifies the role of unrelated events in cost performance of projects. The reporter considered the works of prominent authors on this subject to conclude that events such as international politics and markets, culture, indirect costs from project environment and events in other sectors (e.g. finance, manufacturing, logistics etcetera) all play roles in how dynamic behaviours of costs aggravate. Neither clients nor contractors are able to predict moments of change around these, and how the resultant situations could impact project outcomes. This basic truth is rarely well reported in construction management literature.

A huge volume of work has been reported on overruns. Ahiaga-Dagbui *et al.* (2015:865) think the subject is over-researched however research outcomes are shallow and misleading. For example, there is hardly a shortage of knowledge on overrun causatives (why overruns occur). Intellectual narratives on causations make no complete sense (and can only impact outcomes poorly) unless causality [i.e. how causal agents interrelate with themselves and with effects to transform into noticeable outcomes] is understood. Evidence put forward in this study shows change attribute of prices of major construction materials is multidirectional and this often remains erratic even during business (contract) cycle times. Baloi and Price (2003), Ogunsemi and Jagboro (2006), and Olatunji (2010) have all noted uncertainty around the dynamism of cost variables is the single most important reason why actual costs of project are often unpredictable. Ali and Kamaruzzaman (2010), Cantarelli *et al.* (2012) and Flyvbjerg (2007; 2008; 2011; 2014; 2016) see cost variability, perhaps caused by fluctuations in resource prices, and changes to work scope, as poor practice of estimation resulting from faulty methods and deceptive conducts.

This study reports a relationship between fluctuations in prices of construction material, pre-contract budget and outturn costs; implying surges in budget estimates and overruns can be traced to fluctuations in resource prices. For example, when the prices of cement and aggregates rise, budget estimates for concrete work will rise also. However, the corresponding rise in budget estimates for concrete work may not be explained fully by the rate of change in the constituent resources. This is because apart from simultaneous changes in other cost variables (e.g. costs of plant and labour, on-cost items and risk exposures to external markets), contractors have had to respond to onerous risks transferred to them by extant contract conditions. An example of such situation is established in the results: clients do not consider erratic behaviours of costs often. Estimators can only account for recent and perceived future rises in prices of cement when budgets for cement-based products (e.g. concrete, block walling and finishes) are being developed. Beyond this, there is no significant correlation between outturn costs and rate of change in cement prices. Where cost recoveries are impossible (e.g. when the gap between price fluctuations is not accounted for in outturn payment, or delay in payments) consequences include dissipation in quality of work and rework (Frimpong et al., 2003). Alao and Jagboro (2017) concluded that this is a leading cause of project abandonment by indigenous contractors.

Another dimension to the results under interdependencies between fluctuations in the prices of construction materials and outturn costs is the vulnerability of materials that are available locally to cost changes in global (imported) materials. For example, results show a strong correlation between global commodities such as cement and steel, and laterite earth-fill. A typical explanation for this is supported by Olatunji's (2010) findings on the impact of macro-economic variabilities on construction costs. Such include foreign exchange rates, energy costs e.g. rise in cost of fuel, inflation and aggregated impact of government policies relating to the protection of the local market against risk exposures coming from international markets. For example, a rise in crude prices in the global market means a rise in pump prices of fuel products. Where this is exacerbated by a fall in foreign exchange rates or fuel availability issues, resulting in a rise in landing costs of fuel, the cost of aggregates will rise concurrently as global materials such as cement and steel products.

Through probability distribution fitting analysis, results show likelihoods of change in the prices of construction materials and outturn costs of budgeted line items. For example, there is 15% chance that the price of cement will increase by 38% after 2015; fine and coarse aggregates, 31% and 35% respectively; concrete block and steel reinforcement, 43% and 45% respectively. These are quite significant, even without considering other variabilities such as logistics, storage and protection, inventory costs and construction methods. Further results suggest clients are unlikely to accommodate these changes. Findings show there is only 15% chance that clients will pay 19% more than 2015 costs for block walling despite the possibility of the prices of cement, fine aggregates and blocks rising by 38%, 31% and 43% respectively. The situation is more onerous for concrete; clients will only pay 1% more than 2015 estimates despite the possibility of cement, fine and coarse aggregates rising in prices by 38%, 31% and 35% respectively. Prices of reinforcement may rise by 45%, findings show clients are only keen to raise payment by 12%.

Conclusion

This research investigates cost variability in construction projects by exploring causal relationships between fluctuations in prices of select construction materials and likelihood of variabilities in budget estimates and outturn costs. Evidence from the results show changes in prices of construction materials are chaotic, and are further exacerbated by other factors including amoral behaviours of stakeholders and events that may be unrelated to projects. In addition, these events happen, not as a result of estimators' and contractors' evil or incompetence, rather an obvious 'zemblanity' which much of the research community focusing on overrun causality has refused to acknowledge. Yet the practical implications of this are significant. Without a proper understanding of how resource price fluctuations trigger systemic variability in project costs, not much progress will be made in finding solutions to change events, especially how change agents interact amongst themselves and transform into effects, and how they interact with incipient effects to transform into noticeable outcomes in projects. In addition, evidence from the research suggests the risk avoidance practice in which clients hold contractors accountable for resource price fluctuations is an onerous cultural problem. The industry and the research community must work together to solve this; by way of enlightenment, creating models that reward efficiency and price intelligence, and cost management systems that are open and transparent.

Outcomes reported in this study are limited by scope and location. Only price data of six key materials have been reported, although a typical construction project could require several hundreds of materials, not only different in type but also in quality, application and size requirements. Data used for the study were collected from a developing country where measures to control inflation and public institutions have remained imperfect. Suppliers and manufacturers did not provide the data. Retailers were not contacted individually also. Nonetheless, the methodology used by national newspaper that have published the data regularly over several decades were considered satisfactory. This is because it is incumbent that the newspaper publishers must have contacted many retailers mostly from different locations around Nigeria's major capital cities. Rebates, warranties, discounts, application efficiencies and other cost-saving initiatives have not been included in the analysis, as well as data on human and plant resources and on-cost items.

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