

Proactive Cost Management Model for Building Projects

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Authors' contributions

This work was carried out in collaboration among all authors. Author YJG designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors YGM-H managed the analyses of the study and author YMZ managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aim: Scholars are persistent in calling for proactive management of construction characteristics. Lack of a feasible model continues to daunt the cost objective in the sector. A framework was developed to guide this process of developing a feasible one. This research complements the recommendation aimed at developing a proactive cost management model for building projects.

Study Design: a set of prototyped residential building design was obtained and bill of quantities prepared. Historical cost data collated through secondary sources for ten years was used to generate unit rates and elemental cost history of the prototyped design. The cost of the prototype design was estimated forty times and the yearly incremental or growth rate of each element computed.

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Study Area: Relevant data was collated in Nigeria. Cost data was extracted from the market research reports of the Nigerian Institute of Quantity Surveyor's quarterly publications.

Methodology: the research is underpinned on three constructs that, with best practice, proper knowledge management and predictions the proactive cost management can be attained. Geometric mean was used to compute the cost growth rates and a mathematical forecasting model using incremental rate principle developed. Best Practice Modules and Lessons Learned Mechanism subsystems were also created.

Results: The three subsystems synthesised into the desired proactive cost management model predicts the likelihood of flawed activity and the culpability of associated stakeholder. The mathematical model forecast true cost growth of building elements at various milestone for possible contingency plan. There's no significant difference between estimates and forecast values generated by the model, and the strength of the linear relationship is strong at 0.929571.

Conclusion: This is a feasible tool for stakeholders' proactive cost management. Stakeholders in building contracts can use the model from inception to finish. Project can better be managed and cost efficacy assured.

Keywords: Building projects; cost growth; forecast; lessons learned; model; proactive management; process flow.

1. INTRODUCTION

Historically, construction proves vulnerable to a variety of risks with consequences of undesirable overruns [1,2,3,4] despite the environmental, managerial and technological changes that occurred over the years [5]. Construction vulnerability attributes to poor management of the risks, the approach being largely traditional [6,7]. Traditional management is often too late, too aggregated and too distorted for production planning and control [8]. It is reactive by responding to flaws only after they occur, thus fails to stimulate decisions that can positively affect the overall management efforts [9]. The system eclipses transparency, thus, preventing early identification and correction of production flow inefficiencies and also hindering adequate and timely response to the flaws [8]. Therefore, late delivery, exceeded budgets, reduced functionality and questionable quality of projects result [9]. Proactive management is one feasible remedy to this construction predicament [10,11,12,13]. Identifying and addressing cost and schedule issues in a proactive way minimises the projects risks in construction [14]. Proactive management of construction will bring about the desired level of successful projects objectives envisaged [15].

According to Song et al. [16], proactive is a concept that exploits a prior knowledge about uncertainties to generate a baseline solution, either in terms of schedule or policy. It brings to fore uncertainties in process flow so as to attain to them before they actually occur. The basic steps by Arrow [10] to achieve proactive

management are: there must be formal discussion, documentation, tracking and reporting of project events by the project team in a consistent and structured manner using a recognised and common language. The proactive management model [6,11,16] offers opportunity for preemptive response tendencies to inefficiencies in management processes. The concept "proactive management" entails not only prediction and prevention of flaws, but includes [11] detecting and resolving exceptions as soon as possible when they occur. Being proactive is essentially being forward looking, preemptive or predictive as well as timely responses to challenges in management practice.

Proactive management of construction projects has therefore become so desirable, and is an issue of great concern to scholars [11,16]. A framework to develop a Proactive Cost Management Model (PCMM) has been developed [15] It was recommended that a feasible model be developed to handle the unique construction characteristics. Cost "is the sum of all the payments to the factors of production engaged on the production of a commodity" [17]. This research focusses at developing a feasible PCMM for building projects. The model should not aim to substitute, but complement the prevailing traditional cost management systems [15]. In doing so, the research objectives was to appraise and synthesizes into a feasible PCMM the following:

- a. best practice module that guides stakeholders for a smooth project process flow.

- b. lessons learned mechanism that manages construction knowledge capital and preempt process flaws.
- c. mathematical forecasting model that depicts cost trend from start to finish of a project.

2. LITERATURE REVIEW

Project success is measured by the extent of success in achieving objectives [18]. Among several objectives common to building construction, the factors of time and budget often form the most critical identified. Conversely, budgets often get taunted by unsolicited increase, which literature terms as cost growth, cost overruns or cost escalation. It is an expenditure incurred above what was originally budgeted in the process of acquiring a building facility. Cost growth which often impacts most at the implementation phase of construction contracts may over-extend the client's financial capability [19] to the point where the project may not be finished to expectations, or may even be abandoned, notwithstanding all management efforts.

Literature is awash with factors sneering cost management efforts in construction, causing growth above initial estimates to a disturbing level [20,21]. In effort to better understand the nature of cost growth, it was classified into internal and external factors [20,22]. The internal were described as those factors controllable by the agency/owner while the external exist outside the direct control of the agency/owner [22]. The factors are also classified as either direct or indirect cost growth.

2.1 Incidence of Direct Cost Growth

The direct cost growth is incurred through direct purchases and payments for delivery of goods and services [23,24,25]. Factors under this category are often influenced more by market forces of supply and demand and do change along prevailing market conditions as inflation. SoundTransit [26] reported the inflation situation affecting several major construction inputs which caused significant price rise within a year. One key resource affected by inflation was the material input. Materials can contribute 50 to 60% of total cost of a construction project (Linin et al., cited in [27]). SoundTransit [26] found an average rise in materials and components between 1970 and 2006 reaching 4.4% per annum for three consecutive years. The trend

was almost double in 2003-2006 with an average rise of 7.5%. The study concluded that the risks of continued price escalation in construction undertaking are real and must be accounted for to policy makers and to the public. Similarly, the effect of inflation and interest rate was investigated on the Nigerian economy and the negative impact on the economic growth established [28]. In Nigeria, inflation is a serious malady, yet the measures for inflation control are not sustainable and the interest rate trend so unstable [28], which affects goods and services including construction. The management of inflation therefore, even though difficult, is key to attaining cost efficacy [29,30]. Inflation therefore exerts direct significant pressure on cost of projects which must be controlled for a management model to be feasible.

2.2 Incidence of Indirect Cost Growth

Business processes often encounter some kind of difficulties termed risks, often resulting to indirect cost growth of construction projects [7]. Expenses occasioned by delays, inefficiencies, poor site management and wastages constitute indirect cost on projects [23]. Succinctly explained was how financial risks often occur in form of cost increases leading to excess budget in the procurement of goods and services [31].

The indirect cost incidences in most times, create situations where claims can be advanced. Most flow inefficiencies when turning ideas in construction documents into three-dimensional physical reality are indirect cost factors. Owners, contractors, sub-contractors and consultants affect the level of its impact on projects [32]. As such, the level of impact of indirect cost is determined by the dispositions of stakeholders consequently affecting productivity [33,34]. For example, inactions and poor actions of stakeholders disrupt smooth assembly process and cause delay [5,35]. Researchers in construction projects have established a strong correlation between stakeholders' dispositions in form of delay and cost overruns such that, the causes of project delay are eventually the causes of cost overruns [36,37]. Delay is synonymous to cost [38,37] the aggregation of varying financial loss as a result of delay finally becomes a significant cost component added to the overall projects cost. Delay, apart from contributing to projects cost, often cause distrust, litigation, claims, arbitration, cash-flow problems, total abandonment and a general feelings of apprehension among stakeholders all of which

can contribute to cost escalation of construction projects [23,36].

Flaws and their sources in literature have been studied along- wrong production philosophy [39]; improper planning and control of activities [40,1,41] and incessant change requests during procurement [42,43,44]. Others are poor estimating practice, even when appreciating that estimates often form the basis of contract agreement and also guides the cost management implementation activities [45,46,47, 48,49]. The wrong choice of procurement path [50,51,52,53] and the complex and risk prone characteristics of construction projects [54,55,56,57] that operate in untamed environment [2] are among the significant factors. Techniques/activities to ensure enhanced management practices have been suggested. Recommendations among others include, but not limited to proper production conceptualization [39]; partnering or collaborative production using operational and technical methods; stakeholders and knowledge management (KM); Strategic initiatives and quantitative techniques [58,59,60,61] and lean construction [62]. Despite these recommendations including the availability of various cost control techniques software, it is found that many construction projects still do not achieve their cost objectives, the only remedy of which is good techniques of cost control [63]. Hafez et al. [64] posited that such control techniques should respond early enough against identified flaws so as to eliminate surprises and allow quick corrective actions. Where a control technique is proactive, it will eliminate surprises by responding to flaws more adequately and timely. However, these plethora of recommendations, including existing models and tools still lack the degree of proactive tendency to contain the unique construction characteristics/challenges [65] which calls for a new model.

2.3 The Traditional Cost Management System

Oyinde [63] assessed the cost control techniques used in the Nigerian construction sector in a list of 16 techniques in a questionnaire format. All the techniques related more to traditional cost management system. No respondent identified any additional method in the open ended section of the questionnaire. The research concluded that practitioners are seriously lacking in the use of effective cost control procedures as most

methods in use tend towards traditional method of cost management. Traditional cost management system has problems [66]. The method is irrelevant and even dangerous for managerial purposes (Ploss, 1999 and Kim, 2002 cited by [67]). Apart from the inaccuracy of product cost, the information doesn't stimulate decisions that can affect the overall production result, which is helpless to managers in the product performance improvement task [67]. The traditional system hazes the non-value-adding activities in management process thus, neglecting a key management component that can enhance construction production objectives [68]. Kern and Formoso [67] posited for a dynamic proactive cost management systems in construction that is capable of protecting construction business from the harmful effects of uncertainty. Anyanwu [17] earlier called for "urgent need for innovations in the management of construction resources."

3. THEORETICAL FRAMEWORK

To achieve the research objectives, the theoretical frame is underpinned on the in-depth understanding of cost growth factors and the concept and components of proactive management.

3.1 Cost Growth Factors

Construction complexity generates diverse challenges termed risks and uncertainties [69]. Such challenges are so unpredictable in construction, the consequences often resulting to delayed completion, poor quality standards and higher completion cost above the initial estimate. Suma. Yarlagadda et al. [27] identified cost and time as the main constraints in management functions. In order to enhance construction success level, the risks and uncertainties underlying construction process must be brought under management control through effective means.

In attempt to offer an effective management process as a mean of attaining better cost objective, [22] undertook a study to identify common factors causing cost escalation in construction projects. Seventy [70] cost escalating factors were identified in the literature based study. The culpability of the identified factors were determined and allocated to stakeholders based on their responsibilities. The researchers classified the factors based on their sources, as either from internal or external

related sources. The internal sources were listed as- poor estimating, scope creep, schedule changes, and inconsistent application of contingencies, faulty execution, ambiguous contract provisions, and contract documents conflicts among others. Most of these internal factors relate to the indirect cost of construction which can induce claims during the construction process. The external factors were listed as, local concerns and requirements, effects of inflation, scope changes, scope creep, market conditions, unforeseen events, and errors. The external factors relate more to direct cost, i.e. inducing direct payments. Some cause changes in market prices that the buyer pays directly when obtaining material and services from market sources. The researchers' believed that by identifying key cost escalating factors it will bring about a better understanding of their sources. Feasible strategies, methods and tools can then be developed for better cost escalation management.

Time and cost overruns were studied in Saudi Arabia by [70] focusing on identifying the most significant causes of overruns in the oil and gas construction projects. It was to gain an understanding on the main causes of time and cost overruns from the perspective of the key practitioners in the industry. Thirty eight [38] causes were identified and 48 respondents derived from owner, contractor and consultant's organisations ranked the questionnaires. Mean value was computed for each factor and ranked. Seven groups of causes identified were- all parties related, consultant/designer, contract, contractor, external, owner and resources-related. In Pakistan, factors for cost escalations were studied in the construction sector of the economy. Thirty items from 102 cost escalating factors from literature were shortlisted for a survey [71]. The perception of clients, contractors and consultants regarding the factors of cost escalations were obtained from a five point Likert's scaled questionnaire using weighted average. The research covered different types of projects and it was revealed that cash flow and financial difficulties, slow payments, inflation, fluctuation in material prices, and number of change/extra work orders were the common occurring escalating factors. The common thing in these research findings as well as in the general literature underscore not only a widely spread of cost escalation in developed and developing nations, but cost escalation affects all types of projects including building,

civil engineering, process and industrial construction works. While proper management by the stakeholders can bring down cost escalation according to [22], there are some factors that are beyond the control of stakeholders of the construction industry.

Memon et al. [42] undertook a research on the causes and effect of variation in the Malaysian construction projects. Eighteen causes of variations were collated and sorted out into four groups using principal component analysis. The four groups based on similarity were found to relate to financial and decision management; design and drawings; human and equipment resource and finally client related issues. Three key effect of the variation on projects found to be of significant value were increase in project cost, delay in completion and then logistic delays. The researchers recommended for proper attention by the major stakeholders on occurrence of non-conformities with requirements starting from the beginning of the project to the end as panacea to the undesirable effects of variations.

Al-Hazim et al. [4] acknowledged that cost and time overruns are basic characteristics of most Jordanian infrastructure projects. The differences between the estimated and final cost of infrastructure was established to be between 101% and 600% with an average of 214%, while the range on time overruns was between 125% and 455% with an average of 226%. Apart from establishing the extent of overruns from 40 samples of final reports of completed infrastructure projects, the researchers availed 20 key factors causing overruns. Final recommendations touched on the need for proper planning at the pre-construction stage as well as proper management of the contract implementation. Delay [72] is among the biggest challenges to construction procurement. The survey expressed that, generally construction projects in the developing countries suffer more delay than the developed countries. The impact of delay was further analysed in the Libyan construction economy and the key factors causing delay identified. The critical ones were low skills of manpower, changes in the scope of the project, slowness in giving instructions, and poor qualification of consultants, and also the delay in delivering project site to contractors. Any feasible management model must therefore contain these external and internal cost escalating factors.

3.2 Proactive Cost Management Concept and Components

The concept of proactive management of business undertakings is not entirely new. Attempts have been made to use proactive management as panacea to perennial challenges in the handling of various business processes. Thus, the concept has received varying degrees of attention and defined in varying scientific research directions. The motivation into proactive management in construction has been the high degree of risks and uncertainties underlying delivery processes. Being proactive has essentially been understood, as the best way to handle complex, risky and uncertain characteristics. Therefore, proactive management has been marked out and recommended to be applied to handle the construction complex systems. Meyer et al. [69] developed a framework to manage projects under uncertainties having been motivated by deficiencies noticed in the existing management systems coupled with high level of uncertainties confronting projects. Since then, many fields of knowledge have emphasized on proactive management of systems designs and operations.

In the business field, [11] referred to inefficiency in business process as business exceptions. Business process was defined as a collection of actions, tasks, or steps that should be executed in order to achieve the goals of a company or organization, while business exceptions are events or situations preventing the achievement of business goals and decrease the qualities of the results of business processes [11]. The researchers then introduced a proactive exception handling model by providing comprehensive behavioral, functional, and informational requirements for proactive exception handling from the lifecycle perspective. The model aimed to assist business process performers to predict or detect exceptions and design their processes so that exceptions can be either prevented or resolved on time. Kim et al. [7] were perturbed by two aspects in the nature of prevailing risk management practice in the runtime stage of business processes. The researchers first observed that the prevailing risk management practice lacks a predictive, preventive and mitigating tendency. Secondly, risk management often centers on mitigating the negative effect without considering the positive aspects of risks. Then [7] developed a risk management approach based on behavioral requirements in the view to proactively handle

process-related risks in terms of threats and opportunities. The model offers a predictive preventive means of managing business processes.

After analysing the behavioural requirements of proactive risk management from literature, which made clear the activities required to handle risks during business process execution, [7] proposed a framework for proactive risk management. The framework consists of three components. Two components which are threats and opportunities were further subdivided each into risks predicted and risks detected. The framework is believed to enable risks to be treated in a more comprehensive and timely manner by identifying all mandatory activities, as well as when and where to apply them. The third component developed by the study was a rule language to serve as an implementation model for the systematic support of the proposed proactive risk management approach. The three components were synthesised into a prototype system. The study therefore proposed an integrated risk management approach that proactively handles process related risks in terms of threats and opportunities within the runtime stage of a business process. However, no empirical data was used in the research. Further, apart from being business process specific, the model cannot handle direct cost challenges of construction businesses.

Stefanovic [73] synthesised four subsystems namely, process modelling, performance measurement, data mining models, and web portal technologies into a unique predictive supply chain performance management model. The outcome presented key performance indicators (KPI) projections which also points out emerging trends, opportunities, and problems, thus, leading to more intelligent, predictive, and responsive supply chains that is capable of adapting to future business environment. Schonmann et al. [65] under production technologies posit that modelling and analysing cycles like technology lifecycle and manufacturing resource lifecycle do facilitate a proactive management of production technologies. Conceptual framework was developed to support the timely adequate identification and evaluation of alternative production technologies beneficial in enhancing the performance of production companies. Jantti and Cater-Steel [74] studied some organizations' IT operation activities and found that most of them do rely on reactive approaches in providing

support to their customers. The organizations studied were often reactive rather than proactive in IT operations management. The key recommendations was to be more proactive.

Song et al. [16] considered the concept of being proactive in light of construction project scheduling. According to the researchers, proactive scheduling can effectively handle activity duration uncertainty in real-world projects, by generating a baseline solution according to a prior stochastic knowledge. An approximation approach based on Sample Average Approximation (SAA) was therefore proposed, and a branch-and-bound algorithm to optimally solve the SAA problem developed. The model was tested with empirical results on benchmark problem instances and real-world distribution data. It was found to outperform the best general-purpose approaches that do not exploit the stochastic knowledge.

Understanding construction as an experience-based discipline, [75] also developed a computer based model for proactive problem solving of construction knowledge management. Four subsystems were developed that can classify knowledge and expertise, automatically solve problems through lessons learned, dispatch the unsolved problems to appropriate domain and also accumulate lessons learned for feedback. Synthesised in a computer program, it was demonstrated how the model can be used to improve time and cost effectiveness of the traditional knowledge management systems. The concept of being proactive was applied by [13] to construction change management, but asserted that there is dearth of literature in the field. Furthermore, the 5-dimensional building information modelling (5D BIM) was used to develop a formula to predict time and cost benefit so as to improve the traditional methods of construction in Pakistan [76]. The researchers relied on the collaborative tendency of the BIM technology and set out three objectives to achieve as: understand and examine the uses and benefits of 5D BIM for construction project; make comparative analysis of scheduling and cost of an existing high rise building as done by traditional method; develop 5D model of high rise buildings using software and lastly, make 3D models of different stories buildings and compare with scheduling and cost as done by traditional method. The research found that with increased complexity due to increase in number of stories, cost and time anomaly became more common. The formula developed accepts the number of

stories to pre-empt the extent of benefits in cost and time savings of proposed projects.

The research works in this section underscore lack of feasible PCMM to effectively manage building construction cost characteristics. Gandu et al. [15] then developed a framework to achieve one and recommended for the development of a feasible model to proactively management building construction cost in which this addressed.

4. METHODOLOGY

A feasible PCMM must address the direct and the indirect cost escalating factors. Apart from inflation in prices of goods and services, process flaws in projects must be brought under control [15]. Along this line, a model for proactive cost management was suggested to center on three basic components [15] namely- Best Practice module (BPM), Lessons Learning Mechanism (LLM) and Mathematical Cost Forecasting Model (MCFM). This research therefore complements [15] and developed a feasible PCMM for building construction. The general approach in this work involves appraising the basic proactive cost management components earlier identified and synthesizing them into a feasible management system,

4.1 Data Collection

This research obtained a complete set of designs of a 2-stories prototype residential building and a quantity surveyor prepared a bill. The bill was priced quarterly for ten years and the elemental cost estimate obtained. The composite unit rates used in pricing the bill were generated from a historical cost date (HCD) obtained from quarterly publications of the Nigeria Institute of Quantity Surveyors' (NIQS)'s reports on market survey of goods and services. The bill was priced in line with the HCD from first principle in an elemental format and the total cost of the prototype obtained. Most cost researchers still adopt the elemental format for being the most convenient and better understood construction cost research format (Morton & Jagger, 1995 cited in [77]). In line with the HCD a total of 40 cost estimates of each element of the same building was obtained. The figures at regular intervals revealed how cost changes over time. The summation of the cost of elements also gave 40 historical estimated cost (HEC) of the entire building designed. Using geometrical mean tool, the mean value of cost growth of each element

was computed which reflects the annual rate of change in cost. According to [78], the geometric mean is a more suitable measure of central tendency than arithmetic mean if the data relates to ratios or represent rates of change. The values obtained in this section was used to establish a feasible mathematical forecasting model as one of the components of the PCMM envisaged.

5. RESULTS AND DISCUSSION

5.1 Best Practice Module (BPM) Subsystem

In every process, without best practice, management is a wasted effort because management only complements best practice and cannot replace it. A module for best procurement practice for building construction projects known as Best Practice Modules (BPM) developed by (15) attempted to address flow inefficiencies in construction projects. The BPM is a collation of the best steps to handle each construction milestone but organised into twelve activity modules that span the entire procurement process as follows:

Module 1:

Activity: Supply chain management

Responsibility: Client

Stage: Inception

Actions:

- Carefully select and bring in the supply chain that will deliver design services, supply services, manufacturing and assembling of products.
- Consider as criteria the qualification, experience, and the ability of individuals to work together as part of an integrated project team starting from the earliest possible stage.
- Establish the integrated project team consisting of client and supply chain under partnering principles d. adequate briefing of the supply chain team.
- Properly and adequately brief the supply chain and commission the team.

Module 2:

Activity: Process design and management

Responsibility: Consultants

Stage: Planning and implementation

Actions:

Design actions:

- Understand the user properly
- Write the specifications correctly and clearly
- Design within the best acceptable error limit

Management:

- Decompose the whole process into a work breakdown structure (WBS)
- Understand the customer and its peculiar needs- internal and external customers
- Group similar tasks to reduce the number of steps and number of involvements d. Determine a standard procedure for cluster activities
- Determine the shortest and also compress the cycle time for each cluster
- Identify the flow and conversion sub-processes in each task
- Set up a flow sub-process suppression and a strategy for waste elimination
- Set up a continuous process improvement mechanism
- Set up a lessons learning mechanism for managing internal and external lessons
- Decide on the best transparent process

Module 3:

Activity: Contract Placement

Responsibility: Clients and Consultants

Stage: Planning

Action:

- Study the builder's capability for the proposed project at feasibility
- Prequalify, shortlist and notify all prospective bidders at outline proposal stage
- Issue scheme design and detailed design to all bidders as they are produced
- Invite bidders to bid, select a successful contractor and place a contract
- Decide on proper risk sharing and management process.

Module 4:

Activity: Cost Estimating

Responsibility: Consultants

Stage: Planning

Action:

- Prepare an estimate for the proposed building project in the elemental bill format

- Ensure a complete Cost estimate
- Ensure accurate Cost estimate
- Forecast the risk of the estimate failing
- Advice on cost behavior of the project

Module 5:

Activity: Cost advice

Responsibility: Consultants

Stage: Planning

Action:

- The estimate forms the basis for the awarding of the contract
- Determine the construction period for the project
- Forecast the trend in cost changes at different milestones within the contract period by inserting key variables (to be developed) in the mathematical model to get the total cost at time intervals.
- Depict the results in a line graph to avail change trend in the cost of the project
- Advice on contingency plans against inflationary trend on the entire contract.

Module 6:

Activity: Cost Control

Responsibility: Contractor

Stage: Implementation stage

Action:

- Undertake performance analysis
- Predict cost changes
- Compare actual expenditure at each stage with the projected cost changes
- Identify areas of high cost challenges and act accordingly
- Collate all information for the next stage of the work

Module 7:

Activity: Process monitoring

Responsibility: Client, Consultants and contractor

Stage: Inception, Planning and Implementation

Action:

- Plan for proper process monitoring and control
- Monitor and control process implementation and cost performance
- Feed back to managers
- Comparing results with plans and then

- Taking action against odds

Module 8:

Activity: Lessons learnt process

Responsibility: Client, Consultants and contractor

Stage: Inception, Planning and Implementation

Action:

- Deliberately capture and store lessons learnt from every member in the team
- Process and analyse the information captured and depict the trend for feedback
- Identify the areas of weaknesses of each member from the assessment
- Present the weaknesses at site meetings for discussions and collective decisions
- Repeat the process before each site meeting, document

Module 9:

Activity: Continuous process improvement

Responsibility: Client, consultants and contractor

Stage: Planning and implementation

Action:

- Collate all lessons learnt within and benchmark outside the process
- Evaluate relevant lessons and feed back into the process to improve performance
- Document results and study the trend in the improvement process

Module 10:

Activity: Change management process

Responsibility: Consultants and contractor

Stage: Planning and implementation stages

Action:

- Set up a well-defined change review and control process early
- Evaluate every change initiated to find out how beneficial
- Resist change until it is necessary
- Communicate change accepted early and clearly

Module 11:

Activity: Stakeholders' management

Responsibility: Client and Consultants

Stage: Planning and Implementation stages

Action:

- Identify stakeholders important to the project and list the interest of each member
- Classify the stakeholders according to the power each can exert in the project (critical and less critical ones)
- List the interests and priority of each stakeholder
- Decide on the best management strategy to satisfy every interest

Module 12:

Activity: Strategic initiative

Responsibility: Contractor

Stage: Planning and Implementation stages

Action:

- Decide on parts to industrialise production
- Set up a strong information and communication flow system
- Employ the available information and communication technologies for better performance
- Decide on and employ relevant plant and equipment for optimum performance of the assembly process

The BPM covered key management areas like estimating, planning, inflation, change and other key factors found to affect construction cost performance. It is intended to guide a proper implementation of projects to mitigate flaws. However, where flaws occur, other management theories must apply to prevent failure.

5.2 Lessons Learning Mechanism (LLM) Subsystem

It is difficult to know what is likely going to happen the next day. However, the frequency and pattern of occurrence of events offer clues on when and how such event will occur next. This has been a source of strength in scientific predictive techniques. Hafez et al. [64] availed the occurrence of inhibiting factors against effective cost management of projects in Egypt. Twenty two contractors surveyed identified change order, changes in the design, and errors in the design, current economic situation deterioration, delay project and rising prices of materials as major challenges impeding smooth management flow. Knowledge gap was identified as key blurring factor over the identified

impediments. In Nigeria, [79] found cost challenges including political situations, government policies, economic strains (like inflation, interest rates, etc.), effect of seasonal changes, geographical locations of projects, poor security like insurgency, effects of national elections and corruption. In a study, [80] identified critical factors related to external influences such as suppliers, subcontractors, purchase orders, material handling, equipment and plant hire affecting cost performance of construction. The researchers acknowledged that these factors mentioned are very difficult to control, yet the control being critical to projects success. Omotayo and Kulatunga [80] suggested that the Kaizen Costing, which is an incremental cost reduction approach in managing post-contract cost will present a better solution to cost and time overruns problems of construction projects in Nigeria. Stated further, the method creates better profits, quality and value, and also improves relationships among stakeholders involved during construction activities. However, the findings revealed that kaizen is non-existent in the Nigerian construction industry. Other researchers posit that, as challenges and successes are being encountered in production processes, lessons should be consciously acquired for a continuous improvement of projects process and as antidote to knowledge gap glitch. According to [7], flaws should be identified and addressed more quickly as production processes flows. This suggestion prompted the development of LLM by [15] as a subsystem in a proactive cost management framework. The LLM was meant to capture situations surrounding a project [64,79,80], thus, offering preemptive knowledge acquisition for feedback and continuous improved management technique.

While diverse economic factors directly escalate market prices which can be accounted more readily during purchases, there exists array of factors naturally occurring as well as humanly influenced that disrupt plans and activities causing flow inefficiencies with cost consequences [81,60,41,82], the disruptions which can best be addressed through lessons learned from current events and used for subsequent process improvement are captured in the general factors section in [15]. Various process flow inefficiencies including actions and inactions of the client, consultants and contractors which often constitute reoccurring impediments to project success have also been identified [38,81,41]. The concept of lessons

learned presents that, if a flaw occurs, the same shouldn't reoccur again or at least the negative impact shouldn't be upsetting since we have learned from the previous. To learn from events, common construction flaw factors collated were organised into the LLM that can be applied at all project phases [15]. It was organised in form of a scorecard designed for project stakeholders to periodically assess them and used to obtain the performances index of an ongoing project process (Chart 1). All participants are expected to assess the scorecard in a scale 1-5 to establish "to what extent will these factors impede project success?" (Where 1=very low extent, 2=low extent, 3=average, 4=high extent, 5=very high extent).

The mean is computed thus:

$$\text{Factor's score} = n_1 X_1 + n_2 X_2 + n_3 X_3 + n_4 X_4 + n_5 X_5$$

$$\text{Total score} = 5 \times N$$

(Where n1, n2... n5 represent the number of assessors that ticked either scale 1, 2...or 5 respectively, N= n1 + n2 + n3 + n4 + n5).

a. Mean score of a factor = $\frac{\text{Factor's score}}{\text{Total score}}$

This gives the culpability of a factor to failed project objective measured.

b. The Group Mean score = $\frac{\text{sum of all the factors score in the group}}{(5 \times F \times N_1)}$

Chart 1. Score card for lessons learning

General factors/Scale	1	2	3	4	5	Mean
1 Complexity of the project						
2 Site condition						
3 Weather effect						
4 Political influences						
5 Social and communication amenities						
6 Effect of corruption						
7 Inflation						
Group mean of factors						
Client's related factors						
1 Commitment to project success						
2 Funding of the project						
3 Interruptions and change requests						
4 Appointment of qualified and complete supply chain						
5 Dispute resolution mechanism						
Group mean of factors						
Contractor's related factors						
1 Organizations setting of the firm						
2 Competency and adequacy of workers on site						
3 Relevant equipment						
4 Attitude to site instruction						
5 Subcontractor's challenges						
6 Health and safety measures						
7 Workers' motivation						
8 Dispute among operatives						
9 Availability of labour and material						
Group mean of the factors						
Consultants' related factors						
1 Late issuance of instructions						
2 Level of error and discrepancies in contract documents						
3 Changes requests initiated by consultants						
4 Attitudes to designs						
5 Consultant's team spirit						
Group mean of the factors						

(Adapted from Gandu et al., [15])

(F= number of assessors that assessed a particular section, N1 is the number all the factors in that section).

This gives the culpability of a stakeholder to failed project objective measured.

- c. Project performance index = sum of all the factors scored in the scorecard/ (5 x F₁ x N₁).

(F₁= number of assessors that assessed the score card, N₁ is the number all the factors in the score card).

This gives the performance index of the entire project.

These mean values indicate the culpability of each flaw as well as the stakeholder associated to it, and also the project performance index. The information captured are processed and stored which can be retrieved. Apart from identifying the most challenging flaw factors and the stakeholders' culpability, the analysis of results from different assessments will indicate the likelihood of failed projects if the assessment continue to present poor results. The mechanism offers opportunity for deliberate capturing, processing and reporting documented lessons learned, acquired overtly or covertly, in a structured manner on an ongoing project process. It offers managers foreknowledge of vital information for a proper contingency plan. It is important to note that the factors in this scorecard are not intended to be comprehensive and firm. Each organization may have diverse indices to measure the performance for a project which can be used in the scorecard.

5.3 Mathematical Cost Forecasting Model (MCFM)

Market forces often create changes in prices of goods and services. In order to address cost changes by virtue of market forces, [15] developed a mathematical model using the incremental rate principle. The model avails the future cost of building elements at various milestones by virtue of inflationary changes that might have occurred over time as in equation 1.

$$T_p = \sum_{i=1}^n x_i \left(1 + p \frac{r_i}{4}\right) \quad (1)$$

T_p= total cost, *x_i* =cost of an element, *p* = milestone, *r_i* =annual rate of change in the cost of an element "i".

From equation 1, *T_p* is the total cost of the project at a particular milestone (at point *p*) which is the summation of the cost of all the elements *X* (*i* to *n*) in a building. The value *x_i* is the current estimated cost of an element which can be obtained from first principle (the quantity surveying estimating procedure) given a set of drawings and specifications, while *n* is the elemental number. This work adapted a list of sub elements as in Table 1:

The formula in equation 1 provides that for any change in time, the changes in the cost can be computed by inserting *x*, *p* and *r* values. The summation of the cost of all elements gives the cost of the entire building at *p* timeframe. While the elemental cost and the period can easily be determined, the rate of change in cost *r* must be assessed. Estimated elemental cost of the prototype was computed using the HCD collated. The rate of change in cost "r", for each element was then computed using Geometric Mean statistical tool. This rate of change "r" is simply the mean annual growth in the cost of each element as in Table 2:

6. COMPONENTS OF THE PROACTIVE COST AMANGEMENT MODEL

The analyses consisting of three components (BPM, LLM and MCFM) are discussed below.

6.1 Best Practice Module (BBM)

There is no management theory that abstracts away best practices and expect to come out successful. Cost overruns starts at inception, like poor supply chain setting, poor brief, poor estimating practice, poor planning, incessant change and poor implementation of plans. Proactive cost management therefore should begin by doing the right thing at the right time in a right way throughout a project process [83]. The BPM discussed earlier in the work serve as feasible guide to implementation of sub-processes.

6.2 The Lessons Learned Mechanism (LLM)

For each instance the scorecard assessment in chart 1 is carried out, the culpability of flaws and the stakeholders are indicated including the general performance index of the project. It identifies factors likely to impede the process. Knowledge of these enables contingency plans

against undue occurrences and impacts on cost. The assessment starts from the inception of the project and is repeated over and over until project completion. Values computed are stored for feedback on cost management. As the project progresses, more interactions bring about knowledge through the lessons learned, offering better understanding of individuals and the entire process and each future assessments reflects previous lessons learnt. Information generated from performance evidence as key subjects of solution activities during site meetings.

6.3 Mathematical Cost Forecasting Model

Using the HEC data the Rate of Change (RC) “r” in cost of eleven elements in a building were computed, ranked and presented in Table 3. Four elements from Table 1 were excluded from further consideration as a limitation of the work. The elements including doors, windows, services and external works were excluded for want of clear and consistent HCD after sorting the data gathered from the field.

Notwithstanding, by substituting the values of r from Table 3, equation 1 becomes:

$$\begin{aligned}
 T_p &= x_1 \left(1 + p \frac{0.154}{4}\right) + x_2 \left(1 + p \frac{0.158}{4}\right) \\
 &+ x_3 \left(1 + p \frac{0.118}{4}\right) + x_4 \left(1 + p \frac{0.110}{4}\right) \\
 &+ x_5 \left(1 + p \frac{0.024}{4}\right) + x_6 \left(1 + p \frac{0.326}{4}\right) \\
 &+ x_7 \left(1 + p \frac{0.172}{4}\right) + x_8 \left(1 + p \frac{0.053}{4}\right) \\
 &+ x_9 \left(1 + p \frac{0.081}{4}\right) + x_{10} \left(1 + p \frac{0.067}{4}\right) \\
 &+ x_{11} \left(+p \frac{0.071}{4}\right) \tag{2}
 \end{aligned}$$

Quarterly timeframes were substituted in equation 2 and values of T obtained and the total cost reported in Table 4 as computed cost.

6.4 Testing the Mathematical Model

Values in column 1 of Table 4 are the cost history of the 2-stories prototype design. The estimate was obtained from first principle using the composite unit rates of the quarterly HCD. The first value 554340.752 in column 1 was then used as base value to generate column 2, dubbed computed cost by inserting various values of p and r variables into the mathematical model in equation 1. The two columns (columns 1 and 2) were then compared statistically. The first statistical test is to establish if the samples are statistically different, while the second test computed a linear correlation coefficient to establish the kind of relationship between them.

In order to find out in statistical terms if there is significant difference between the estimated cost and the computed cost, a t-distribution was used. If the columns are different, it means the computed cost cannot reliably represent the estimated cost, otherwise. The hypothesis:

H₀: there is no significant difference between the estimated cost and the computed cost.

H₁: there is significant difference between the estimated cost and the computed cost.

The t-value computed using spreadsheet is 0.138495. The critical value at 5% level of significance is 1.684. The computed value of “t” is less than the critical value. Then accept H₀ that there is no significant difference between the estimated and the computed cost in accordance to the hypothesis. Table 5 also indicates that there is a high positive correlation between the estimated and the computed costs. The linear correlation value of 0.929571 shows strong positive relationship between the actual estimated values and the computed values under study.

Table 1. Building elements

Elemental nr. (n)	Elemental name (x)	Elemental nr. (n)	Elemental name (x)
1	Substructure	9	Doors
2	Frames	10	Services
3	Staircase	11	Fittings and fixtures
4	Upper floors	12	Wall finishes
5	Roof	13	Floor finishes
6	External walls	14	Ceiling finishes
7	Interior walls & partitions	15	External works
8	Windows		

Table 2. Elemental cost changes

Elemental Nr.	Element identity x	Annual Rate of change in cost r
1	X_1	r_1
2	X_2	r_2
3	X_3	r_3
.	.	.
.	.	.
n	X_n	r_n

Table 3. Result of the yearly incremental rate of change in cost of elements

Elements Nr. and Name	Element identity	RC (Yearly r)	Rank
1. Substructure	X_1	0.1540	4
2. Frames	X_2	0.1580	3
3. Upper Floors	X_3	0.1180	5
4. Roof	X_4	0.1100	6
5. Staircase	X_5	0.0236	11
6. External Walls	X_6	0.3260	1
7. Internal Walls & Partitions	X_7	0.1720	2
8. Walls Finishes	X_8	0.0525	10
9. Floors Finishes	X_9	0.0810	7
10. Ceiling Finishes	X_{10}	0.0670	9
11. Fittings & Fixtures	X_{11}	0.0710	8

Table 4. Estimated and computed cost of a prototype building

Year	Estimated cost	Computed cost	Year	Estimated cost	Computed cost
1998	5543490.752	5543490.752	2003	6471873.305	9195802.264
	5777803.975	5726106.328		6701752.075	9378417.84
	5785450.037	5908721.903		9393062.355	9561033.415
	5331888.104	6091337.479		9393062.355	9743648.991
1999	5170569.647	6273953.055	2004	10004692.4	9926264.567
	5671886.964	6456568.63		10965973.85	10108880.14
	5717674.642	6639184.206		10965973.85	10291495.72
	5609369.325	6821799.781		10965973.85	10474111.29
2000	5908175.046	7004415.357	2005	11679391.48	10656726.87
	5928254.521	7187030.933		11416180.27	10839342.44
	5802757.02	7369646.508		11416180.27	11021958.02
	5802757.02	7552262.084		11284574.67	11204573.6
2001	5802757.02	7734877.659	2006	11814493.98	11387189.17
	5802757.02	7917493.235		12171932.14	11569804.75
	5802757.02	8100108.811		12171932.14	11752420.32
	5710840.399	8282724.386		12369340.55	11935035.9
2002	6091356.852	8465339.962	2007	12369340.55	12117651.47
	6091356.852	8647955.537		12369340.55	12300267.05
	6091356.852	8830571.113		12919278.21	12482882.63
	6091356.852	9013186.689		13408343.32	12663689.3

Table 5. Linear correlation coefficient

	Column 1	Column 2
Column 1	1	
Column 2	0.929571	1

When estimated cost increases, the computed cost also increases. It therefore signifies that the computed cost is a true representation of the estimated cost in Table 4. Therefore, the mathematical model can be relied upon to project

the actual increase in cost of a building over time.

7. THE PROACTIVE COST MANAGEMENT MODEL

Fig. 1 is the proactive cost management model that addresses the cost growth incidences. It is a synthesis of the three management components developed and namely (BPM, LLM, and MCFM) that works as a system. The application of the model to control cost covers all stages of the construction process and starts at the inception stage. The client who initiates the project begins by applying the best practice module in his functions of setting up a supply chain, the role

outlined at the BPM. The client sets up a competent supply chain and commission then after briefing them adequately. Lessons acquired previously or currently are applied in the process. Then a review is done and when satisfied with the result, the next stage in the model is implemented and the results documented. The consultants' best practice also outlined in the BPM begins when commissioned. The planning role spans through the planning process until the contractor is appointed. The role includes designs practices, estimating and contractor selection. Proper planning safeguards and reduces possibility of cost challenges during contract implementation.

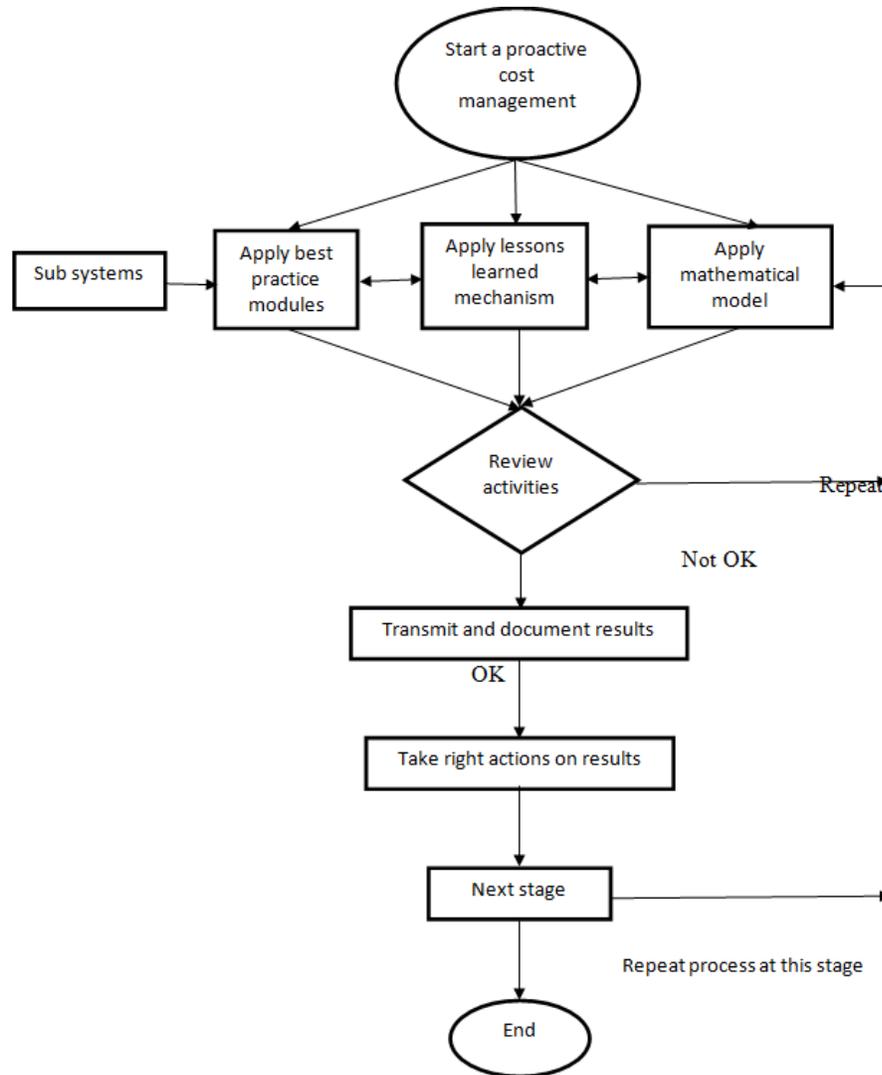


Fig. 1. Proactive cost management model

The Scorecard identifies likely flaws and depicts the readiness of the team members. The LLM assesses those inefficiencies likely to be encountered and the sources of the inefficiencies. The mathematical model is applied on the estimate to depict the pattern in cost changes at various milestone by virtue of market forces. This serves as an alert to stakeholders on the nature of inflation in the process. The information is important in taking contingency measures to control cost due to inflation and also inefficiencies that will impact on the cost.

The contractor can use the model in monitoring and control of construction activities. The best practice modules, scorecard assessment and cost prediction model are relevant in the implementation process. Repeating and documenting results from the model implementation offer opportunity to deliberately learn and capture lessons as the work progresses all through the project duration. The model encourages members to work as a team in each stage of the management process and there is better likelihood of cooperation in the execution of the project. The model therefore presents a logical management system that offers a proactive tendency in managing construction cost.

Proactive management starts at the onset throughout the entire stages of the construction product development as the management components of the model are applied logically. Information obtained at each stage of evaluation are used as feedback into continuous process improvement.

7.1 Model Validation

The proactive cost management model was validated by a focus group opinion panel of highly experienced construction managers assembled from ten construction companies in Nigeria. All members of the panel have spent over 25 years in construction experience. Members were first asked to list management challenges frequently impeding construction cost efficacy. The challenges listed includes the market related like inflation and scarcity, and also flow inefficiencies like delay, waste, etc. which have often caused cost overruns. The proactive cost management model was presented as a tool to manage the identified flaws and the team assess how the model can solve construction challenges if applied. The components of the model were matched with diverse challenges to

avail the relevance against each flaw. The panel rated the model as very proactive at the end of the exercise with a paradigm shift in the way management is being practiced in their organisations. The model was scored to be at 80% success rate in cost efficacy if construction managers implement it properly in construction management.

8. CONCLUSION AND RECOMMENDATIONS

The traditional management system is not meeting the needs of construction undertaking and proactive management has been recommended as the solution. Three key components that can guarantee a proactive cost management are the best practice, lessons learned and forecasting of events. These subsystems developed but synthesised into a model offers a feasible proactive management tool. The model preempts process flaws, guides best practices, manages knowledge and forecasts cost trends of building elements in a unique way during procurement. Thus, guarantees timely and adequate responses to construction challenges in line with proactive requirements. This study has contributed to the body of knowledge by adding to the extant literature and yet covering the gap of non-existence of feasible models so created by researchers in the field of proactive cost management. While contractors can use the model for proactive construction management, consultants can benefit by using it as a cost monitoring system to avail improved management related information for quality services to the client. This offers a paradigm shift in the way management is done. The construct generally offers a new way of inquest into the proactive research field.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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