A CONTINUOUS IMPROVEMENT FRAMEWORK USING IDEF0 FOR POST-CONTRACT COST CONTROL

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ABSTRACT

Advancements in construction project management have necessitated a comprehensive rethink of construction project processes. Gantt charts and critical path analysis have been produced to create a work breakdown structure which can identify challenges and crucial infrastructure development activities which can have an adverse impact on the project. However, they do not improve the construction process. Integration Definition Language 0 (IDEF0) models present an opportunity for construction project managers to identify essential workflows during construction and improve them. The improvement process is continuous. Hence, kaizen, which is part of lean construction, can be implemented. This study demonstrated the use of IDEF0 in a building construction project in Nigeria where the construction companies have issues with cost, overruns, low competitive advantage and unsatisfied clients. The build up to the challenges identified post-contract cost controlling techniques as an important variable in establishing the challenges above in the construction industry. With the aid of Kendall's coefficient of concordance, the analysis was carried out to determine the techniques which are most important and effective in managing construction costs during the execution phase. Monitoring building material cost was identified to be the most important technique. The recognised significant and effective techniques were used to build a continuous improvement model with accompanied drivers such as the working budget and monitoring of overheads. The output of the findings was presented in an IDEF0 model with some written guidelines. The model designed in this study can be used on construction sites by cost and project managers to reduce and maintain current costs from the working budget through continuous improvement.

Keywords: Cost controlling techniques, continuous improvement, framework, kaizen costing, post-contract

INTRODUCTION

ICAM definition for function modelling (IDEF0) is a process improvement tool

which is usually available on Microsoft Visio. ICAM is an acronym for integrated computer-aided manufacturing (Veis et al., 2009). IDEF0 is similar to a Gantt chart, and network diagram. However, IDEF0 allows professionals to view complex processes from a clearer perspective (Veis et al., 2009). IDEF0 is mainly used for business process re-engineering, production planning and control, integrated product development, just-in-time, and construction process improvement (Mayer et al., 1992; Soung-Hie and Ki-Jin, 2000:, Veis et al., 2009). Basically, IDEF0 is used to organise workflows in a more logical and simplified manner to create a model of activities. This model is embedded in a framework which is generally used to improve the business process. The primary components of IDEF0 are the input control, mechanism, function and output (Hirao et al., 2008, Imran et al., 2010). IDEF0 is used for process improvement which is related to continuous improvement of activities. There have been challenges in the construction industry. Major challenges include stiff competition for project opportunities in Nigeria, cost and time overruns, operation management problems and poor production quality. IDEF0 can be used to mitigate the aforementioned challenges by identifying the input, control mechanism and final output of the work package. The IDEF0 process is illustrated below.

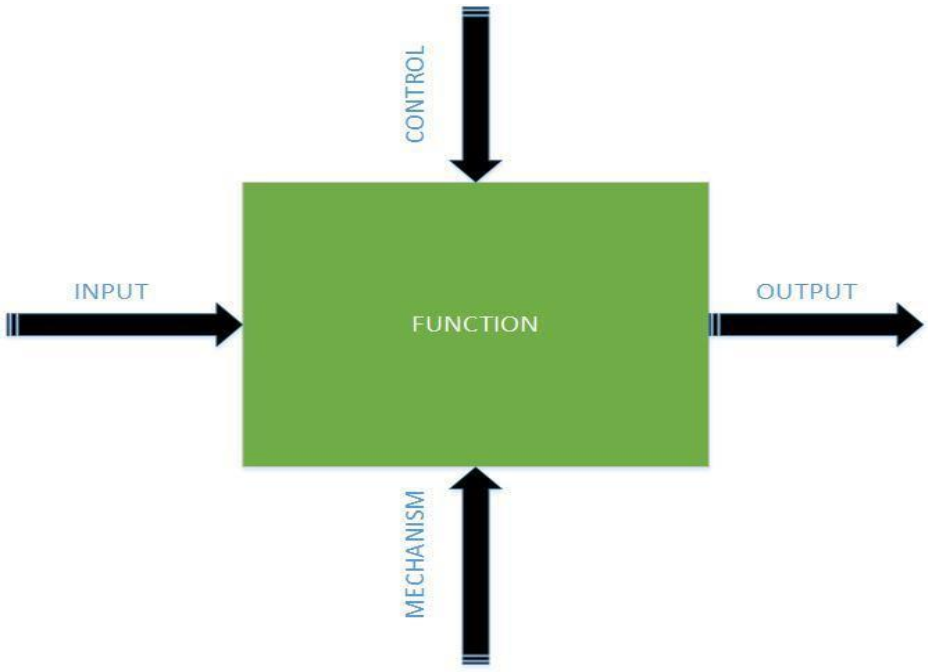

Figure 1: The IDEF0 process (Adapted from Soung-Hie and Ki-Jin, 2000)

According to Soung-Hie and Ki-Jin (2000), in the IDEF0 illustration above the function is the activity which will be carried out; the inputs are factors which the events may alter; the control is external constraints which may impede the success of the construction operations while the mechanism is the tool or means to fulfil the

action. The output is the result of the activity. To represent the framework in this study, the IDEF0 is decomposed into various activity groups. The design of IDEF0 for a process or activity is based on an existing process which has to be improved. In this study, it will relate to the post-contract cost-controlling techniques in Nigeria. The aim of this study was to demonstrate the usefulness of IDEF0 as a continuous improvement tool in post-contract cost control. Therefore, the performance of post-contract cost controlling techniques used in Nigeria was evaluated.

Post-contract cost controlling procedure in Nigeria

Post-contract cost control starts from the initial budget that has been planned. An interim valuation follows this at the construction stage. At the construction stage, the contractor cash flow is prepared to monitor the project finances to ensure profitability (Sanni and Hashim, 2013). Another technique used in monitoring construction cost during execution is earned value analysis (Hunter et al., 2014). New techniques involving an intranet-based cost controlling system have also been proposed by Abudayyeh et al. (2001). Measuring work on the site may also include methods such as cost ratio calculation, incremental milestone, units completed and weighted units (CII, 2000). Managing cost during construction involves making the right decisions at the right time and ensuring the cost of each activity does not go beyond the projected cost.

Cost control of any project starts from inception and ends at the completion with the issuing of final certificates (Ashworth and Perera, 2015). According to Ashworth and Perera (2015), the post-contract stage of a project begins from when the contract is signed to the final account and certificate. The process of controlling cost in the post-contract stage is detailed as:

1) Interim valuations and payment certificate,
2) Cash flow and forecasts through budgetary control,
3) Financial statements showing the current and expected final cost for the project, and
4) Final account, the agreement of final certificate and the settlement of claims. (Ashworth and Perera, 2015).

The choice of a method of controlling the cost of a project during the post-contract stage depends on the contractor's selection method; the price determination method for the tender and final account; client or contractor control; and the duties of the quantity surveyor in managing the budget and account (Ashworth and Perera, 2015). The four main stages highlighted above may vary depending on the type of construction project. Every construction project and the teams involved in any construction project are unique. Therefore, the method used in controlling cost during a project will also be exclusive. The various techniques

identified according to the relevant literature are explained in Table 1 that follows.

Table 1: Post-contract cost control techniques

S/N	Post-contract cost controlling techniques	Reference
1	Cash flow	Ashworth and Perera, 2015; Sanni and Durodola, 2012; Sanni and Hashim, 2013
2	Taking corrective action	Ashworth and Perera, 2015; Sanni and Durodola, 2012
3	Monitoring overheads	Ashworth and Perera, 2015; Sanni and Durodola, 2012
4	Monitoring labour cost	Ashworth and Perera, 2015; Sanni and Durodola, 2012
5	Monitoring material cost	Ashworth and Perera, 2015; Sanni and Durodola, 2012
6	Monitoring equipment cost	Ashworth and Perera, 2015; Sanni and Durodola, 2012
7	Managing variations	Olawale and Sun, 2010; Ashworth and Perera, 2015; Sanni and Durodola, 2012
8	Intranet based cost controlling	Abudayyeh et al., 2001
9	Unit rate	Olawale and Sun, 2010; Ashworth and Perera, 2015
10	Interim valuations	Ashworth and Perera, 2015
11	Incremental milestone	CII, 2000; Leu and Lin, 2008;
12	Site meeting and post-project reviews	Ankur and Pathak, 2014; Leu and Lin, 2008; Czarnigowska,

		2008.
13	Identifying indicators of cost overruns	Ashworth and Perera, 2015; Olawale and Sun, 2010; Sanni and Durodola, 2012
14	Summarising profit and loss	Sanni and Durodola, 2012; Ashworth and Perera, 2015.
15	Site meetings	Puvanasvaran et al., 2010; Berger 1997; Chukwubuikem et al., 2013
16	Cost ratio	Sanni and Durodola, 2012
17	Cost forecasting	Sanni and Durodola, 2012; Czarnigowska, 2008
18	Using established budget and targets	Sanni and Durodola, 2012; Ashworth and Perera, 2015

(Source: Authors)

Improving post-contract cost controlling techniques using kaizen costing

The term 'continuous improvement' or *kaizen* has become common in many organisations in the world. Contrary to the belief of many authors that kaizen started with the Toyota production system (TPS) along with lean production, Shang and Pheng (2013) argue that kaizen started in the United States when the government started the "training within industry*"* programme during the World War II, before it was brought to Japan. Continuous improvement is not only relevant to performance management but also to production management in both large corporations and small- and medium-scale enterprises (SMEs). Lean thinking and continuous improvement have been harnessed by many organisations as tools for improved performances in all divisions. Koskela and Ballard (2012) argued that failure to leverage the concept of product in management has led to challenges in the field of management science for half a century. The use of production techniques such as lean production in construction has been a major subject of discussion in academia. The concept of lean production has significantly improved the cost, quality, client satisfaction and construction project delivery (Sacks, Koskela, Dave and Owen, 2010). Studies in the area of lean production involved case studies of various industries other than the construction sector. Therefore the benefits highlighted by

Sacks et al. (2010) have cut across these sectors.

In this investigation, the post-contract cost control process will be improved using the Plan-Do-Check Act (PDCA) principle of kaizen. According to Puvanasvaran et al. (2010), another approach to kaizen costing involves the PDCA process. This process includes the following seven stages:

1) Defining the plot area or section which requires improvement;
2) Identifying the losses from non-value added activities which are documented in a template;
3) Scheduling the activities to be reviewed for solutions;
4) Organising the project team to brainstorm possible solutions;
5) Implementing the solutions involving PDCA. PDCA also includes research, data collection and analysis;
6) Confirming the effectiveness by looking at before and after approach, and
7) Following up with the implemented plan requiring a checklist sheet, employees, the top management.

These steps will be applied to the process involved in techniques used to improve the identified post-contract cost controlling techniques in Table 1. Hence, the methodology for process follows below.

1. RESEARCH METHODOLOGY

A survey strategy was used to collect data from eighty-three (83) construction companies in Lagos, Nigeria. The companies responded with one hundred and thirty-five questionnaires out of two hundred and fifty (250) questionnaires which had been distributed to the quantity surveyors and project managers in these small- and medium-scale construction companies (SMSCCs). The Kendall W test was used to rank these post-contract cost-controlling techniques afterwards. The Kendall W test is a non-parametric test. According to Legendre (2005), Kendall's coefficient of concordance (W) is a measure of the pact among several (p) judges who are assessing a given set of n objects. This test evaluated the degree of similarity between two sets of ranks for the same round of variables. This level compares each variable as a pair to rank the most important variable. Mehta and Patel (2012) noted that the Kendal W test is a scaled Friedman's test with the formula:

$$W = \frac{Tf}{N(K-1)} \quad (1)$$

The test produces the p values which are the asymptotic p-value. If the p-value is less than 0.05, this is acceptable. Also, Kendall's coefficient of concordance (W) should also be less than 0.05 for fair values (Mehta and Patel, 2012). The ranking

produced by Kendall's W coefficient of concordance is a form of measure of association (Mehta and Patel, 2012). Legendre (2005) further noted that Kendall's W is the measure of the degree to which the *K* applicants agree with the *N* judge. The N measures the level of effectiveness or importance of the various post-contract cost-controlling techniques which are used by small- and medium-scale construction companies in Lagos, Nigeria.

The most effective techniques used in post-contract cost control are the techniques which lead to successful implementation. The techniques that produce the desired results when required are the most useful. Therefore, these techniques have more impact on the entire construction project during the execution phase. The most important post-contract cost controlling technique is the one which cannot be left out during the post-contract cost control activities. These techniques are processes which the cost or project manager needs to adopt during construction to ensure that the project stays within budget. It is imperative to evaluate the useful and relevant post-contract cost controlling techniques because they are used to address the problems facing traditional post-contract cost control in small- and medium-scale construction companies in Lagos, Nigeria. The evaluations are required to understand implementable strategies for kaizen and kaizen costing in these types of organisations, based on the respondents' perception of these techniques.

The Kendall coefficient of concordance (W) was applied to evaluate the level of agreement between the various post-contract cost controlling techniques and the respondents' Likert scale ranking. The purpose of this was to assess the most efficient post-contract cost-controlling techniques and also to determine what techniques small- and medium-scale construction organisations in Lagos are using. The results of this test assisted in comparing the present level of the post-contract cost control system used in practice in Nigeria with what is used in other developed countries such as the United Kingdom, Japan and the United States of America. The purpose of the effectiveness test is to provide a clear understanding of the requirements for a framework necessary for the implementation of kaizen costing in small- and medium- scale construction companies in Nigeria.

Effectiveness of post-contract cost controlling techniques

From the chart below, the technique which involves monitoring material cost ranks the highest with a value of 11.33; and interim valuations are perceived to be the second most effective with a value of 10.98. The use of an established working budget such as cost information from the bill of quantities, preliminary items of work and material schedule ranks third with a value of 10.62. Taking corrective action and monitoring equipment cost have a value of 10.61 and 10.41 respectively. They ranked fourth and fifth. The least most effective post-contract cost control technique is cash flows. This has a value of 7.85. Other less effective techniques are variation management, cost forecasting, profit and loss summary, and cost ratio, with values of

7.86, 8.09, 8.4 and 8.4 respectively.

The degree of agreement of this ranking of Kendall's W is given as 0.05. Kendall's W value is always between 0 and 1. 0 indicating that there is no agreement between the respondents, while 1 indicates a perfect agreement (Pallant, 2009). The respondents' positions on each of the post-contract cost controlling techniques are not in complete agreement with each other. The respondents have divergent opinions concerning this question as indicated by the result. Nonetheless, there is a significant association between the post-contract cost controlling techniques and the respondents.

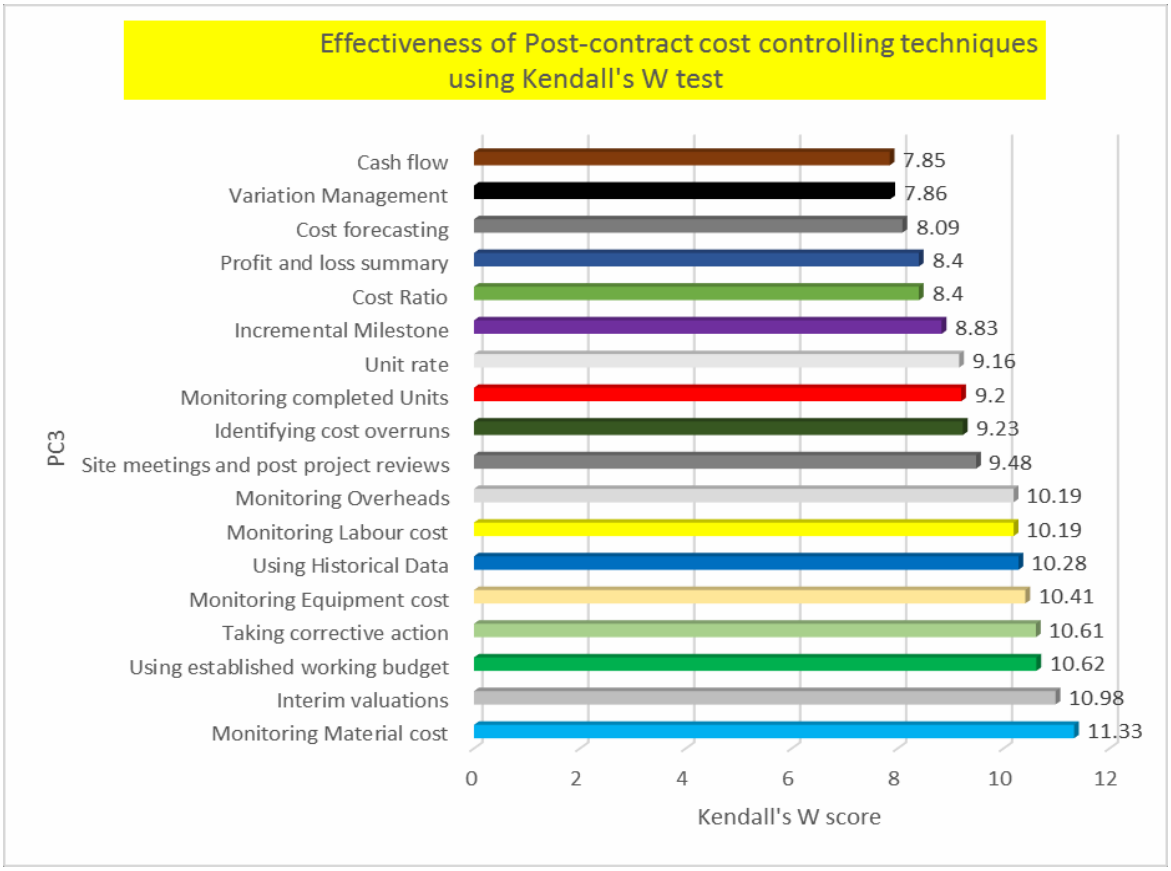

Figure 2: Effectiveness of post-contract cost control

The respondents prioritised these post-contract cost control procedures as listed above in descending order. The asymptotic significance value was also less than 0.05. Therefore, there is a high significant association between the respondents and the techniques.

Table 2: Kendall's W test for effectiveness of post-contract cost controlling techniques

Criteria	Figures
N	135
Kendall's W	0.050
Chi-square	113.973
Df	17
Asymp. Sig	0.000

(Source: Authors)

Kendall's coefficient of concordance for the most important post-contract cost controlling techniques

The Kendall's coefficient of concordance test explained in section 2.0 would also be used for this analysis. Kendall's coefficient of concordance also ranks the various techniques in descending order. Monitoring material cost had a value of 11.44. Monitoring labour cost had a value of 11.26 and is ranked second, while profit and loss summary, using established the working budget, site meeting and post project reviews were ranked third, fourth and fifth with values of 11.13, 11.03 and 10.43 respectively. The least most important technique is variation management with a Kendall W score of 6.88. The cost ratio is second least most important with a Kendall W score of 8.01. Other techniques ranked by the respondents are monitoring overheads, cash flow and using historical data. These techniques have values of 8.31, 8.37, and 8.62 respectively.

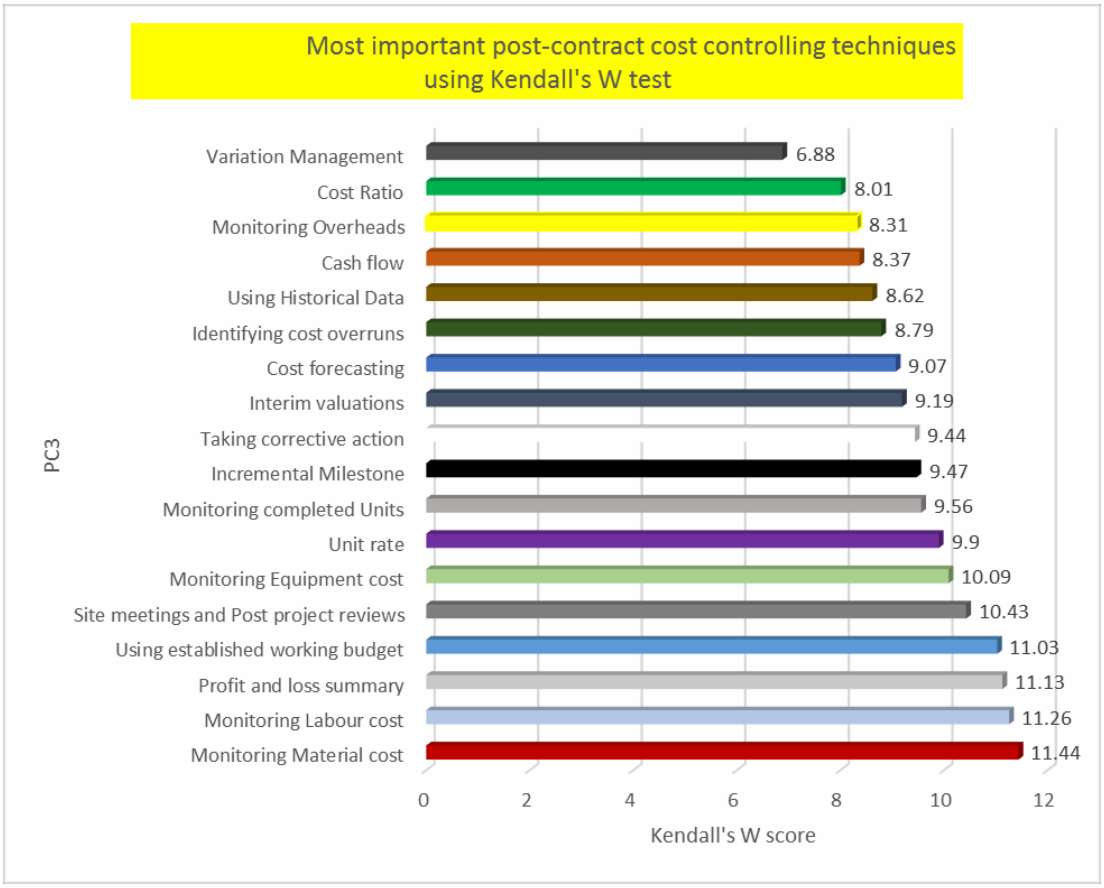

Figure 3. Important post-contract cost control techniques

The Kendall W score of 0.043 shows an insignificant level of agreement for the most important post-contract cost controlling techniques and the respondents' rankings on the Likert scale.

Table 3: Kendall's W test for important post-contract cost control techniques

Criteria	Figures
N	135
Kendall's W	0.043
Chi-square	145.451
Df	17
Asymp. Sig	0.000

(Source: Authors)

The asymptotic significance value is also less than 0.05, thereby reflecting the importance of the respondents and the techniques.

DEVELOPING THE IDEF0 MODEL

Quantitative analysis was carried out on the types of PC3 techniques in Nigeria with the aid of Kendall's coefficient of concordance test to rank the PC3 and also to evaluate the level of agreement among the respondents. This was analysed in figures 2 and 3. The evaluation aspect of the objective was carried out using Kendall's coefficient of concordance. The Kendall's W test ranked the various post-contract cost control techniques, and also evaluated the most effective and most important techniques. The most effective and most valuable techniques were identified as monitoring material cost. Cash flow was ranked lowest as the least efficient technique. Variation management is considered to be the least important technique. Using a working budget during the construction process was ranked second as an effective technique. The bill of quantities, according to Rad (2002) and Oyedele (2015), has inaccuracies with the use of measurement CAD software. Once there is a problem with the design, there will be inaccurate estimates.

Ashworth and Perera (2015) highlighted the first major steps of post-contract cost control as being monitoring and interim valuations, cash flow, monthly statements, and issuing final certificates. The techniques were not highlighted. Monitoring cost involves performance metrics (Oyedele, 2015), and cost controlling activities depend on whether the processes on the site are within budget. Some of these processes include the site visit, meetings, monthly cash flow calculation and payment of contractors. Some authors argue that one cannot control cost but only monitor what is going on during construction and then take corrective action. The debate between cost monitoring and control activities may only be because of the semantics. For this investigation, cost control is the art of reducing unnecessary expenses during construction, while budget monitoring is the process of ensuring the project is within the established working budget, hence the bill of quantities.

Kaizen costing for post-contract cost control in the IDEF0 framework

Kaizen costing pertains to reducing expenses during construction and maintaining quality for maximum profit and client satisfaction (Mĺkva et al., 2016; Knechtges and Decker, 2014; Radharamanan et al., 1996). Therefore, the controlling activities on a site based on the techniques should include the principles of plan-do-check-act. The plan-do-check-act will require one of the professionals to be actively involved in the PDCA process. The framework for post-contract cost control will require monitoring activities as interim valuations as a primary approach for incrementally reducing the expenses on site. The IDEF0 model will be used for this process.

IDEF0 process for post-contract cost control process

The IDEF0 is a modelling technique for process improvement. This model has been explained earlier. The model is usually carried out to reflect the normal process and the model that has been improved. In this study, the improved process has been developed for the framework. This is displayed in Figure 4. After the award of contract and the mobilisation fee has been paid to the contractors, the construction process commences. This process makes use of the working budget. The overall aim of the contractor is to make a profit and provide the best quality product on time to a satisfied client.

The IDEF0 process in figure 3 starts with cost monitoring and control activities using a well set out standard for construction. Interim valuations are conducted at intervals based on the Gantt charts or programme of works. The units completed based on the tender sums are sent to the client's quantity surveyor for interim payments. This process has to consider the overhead expenses which are monitored. Some of the overhead expenses include the water, access roads, electricity, sanitation, office overheads such as stationery, tables, chairs and other necessities associated with the preliminary items of work. The elimination of unnecessary activities and waste in the preliminary item of works is essential. PDCA is implemented at this stage. An employee may be appointed as a supervisor to monitor this process for timeous corrections. Taking corrective action is imperative to the implementation of kaizen costing during post-contract cost control.

The stage payments will be entered into the cash flow for calculations. This is connected to the monitoring activities for plant, labour and materials. The contractor quantity surveyor has to reduce and maintain the subcontractors' quotations and therefore negotiation skills may be required at this stage. A consultation process is necessary for labour rates and plant hire. The PDCA also comes into the negotiation skills to identify the best activities for reducing the cost of labour, material and plant. Reducing the cost of labour may not be ideal in developing countries, but kaizen costing may ensure that the labour cost is maintained and the right workers are paid for the right activities. The monitoring of plant, equipment and labour is crucial for kaizen costing implementation. Overhead costs relating to material, labour and plant

may be reduced continually for the attainment of a suitable final construction cost. This process is repeated during each stage of interim valuation and cash flow.

Variation management is another aspect where the contractor quantity surveyor may lay claims to change the design. Variation management and financial constraints on the part of the client may lead to disputes, cost overruns and project delays. In Nigeria, variations and changes have caused many projects to be abandoned. Therefore, the quantity surveyor and project manager (who may be an architect) need to work together to effect a speedy resolution. The PDCA process can be adopted for the elimination of unnecessary activities, products, and waste when conducting variation management.

The quantity surveyor will then prepare the final financial certificate, which is a statement of the overall construction cost. In many projects, the budget of the project is not always equal to the final tender sum. There may be a slight overrun on the budget. Nonetheless, most projects involving kaizen costing during the production phase have always experienced increased profit, project completion on time, quality delivery, satisfied client, improved competitive advantage and project performance.

CONCLUSION

The findings showed that monitoring the cost of material is the most effective and important technique on site. Monitoring the cost of materials has to do with inflation, transportation of material to site, purchase order, and quotation from supplier and sub-contractors. The entire concept of monitoring is paramount to the contractor because this is where the profit lies. Monitoring of labour rates on the site is also essential. The prices of materials and labour may vary from state to state in Nigeria. However, this study was based on Lagos, Nigeria where the prices are fairly stable. The cost of building materials for building construction may fluctuate during the duration of the project. Building material supply is also connected to other critical success factors, namely construction business and ethics, which may be investigated for further studies. Many fraudulent practices take place during development activities in Nigeria, and these include bribery, the kickback of funds and the inflation of prices, which affects the quality of cost information. Corruption in the Nigerian construction industry is a major factor that may hinder the effectiveness of any approach to cost management.

Another useful technique is using a working budget. The working budget is the bill of quantities, and it is always riddled with errors right from the planning phase. These errors are carried over to the execution stage. Nonetheless, a working budget is very effective if the unit rates from the budget and quantities are meticulously monitored during the planning stage. The management of variation and cash flow calculation were added to the framework but were ranked very low in the analysis. Many factors might be responsible for this, but it requires further investigation. The changes in post-contract cost control have to evolve over time. The change can be

carried out using kaizen. Hence, kaizen which is a form of continuous improvement, may exist in small and medium-sized construction companies in Nigeria.

IDEF0 has a way of identifying the primary processes which may assist the quantity surveyor or project manager to improve the entire construction process. The time it takes for the improvement will not affect the whole construction project because the identified problems are resolved immediately. However, further research could look at the cost implications of having this type of framework for PC3.

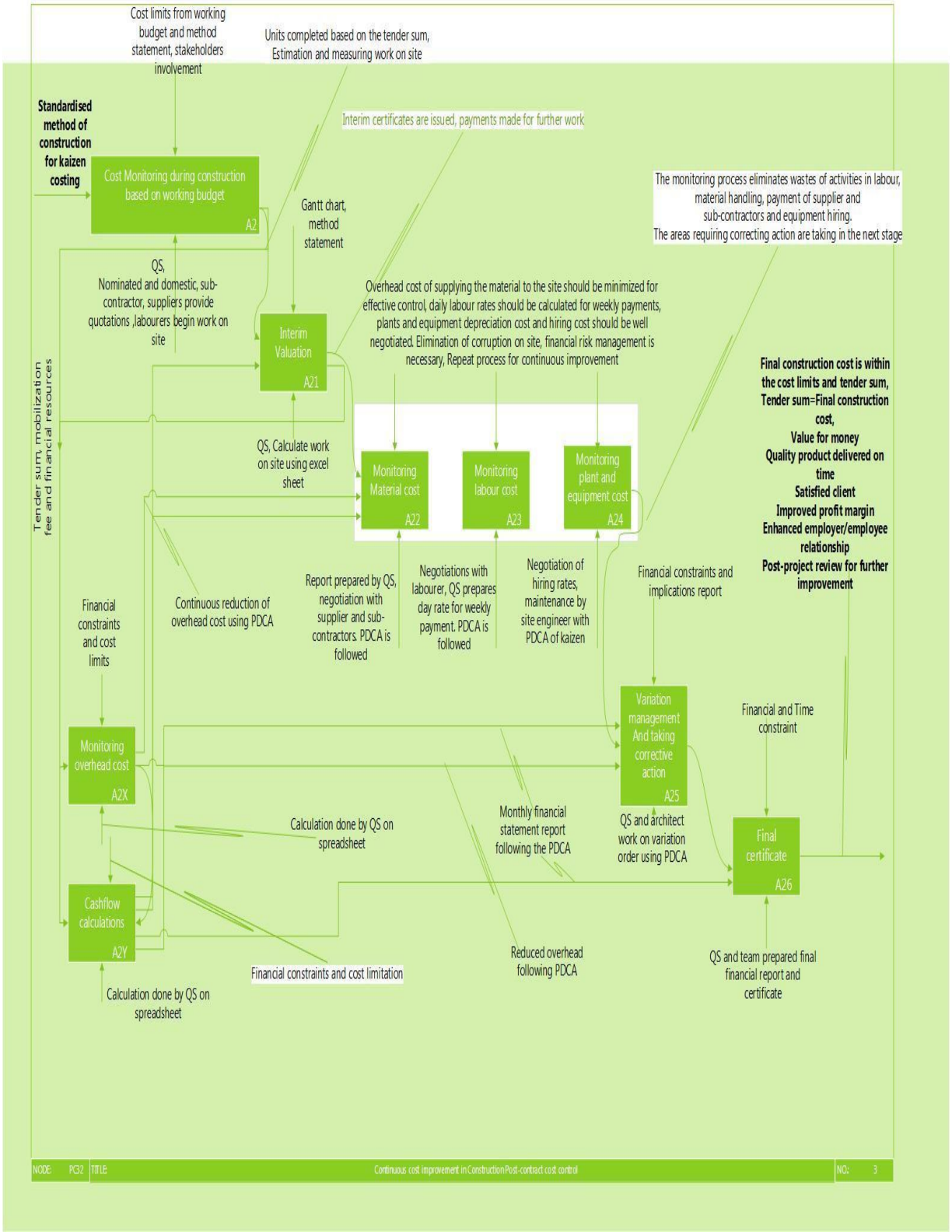

Figure 4. IDEF0 process for post-contract cost control of a hypothetical building construction

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