

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, presents 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 cost 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 overhead. The output of the findings was presented in an IDEF0 models 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.

1. 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 Gantt chart, network diagram. However, IDEF0 allows professionals view complex processes from a more clear 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.

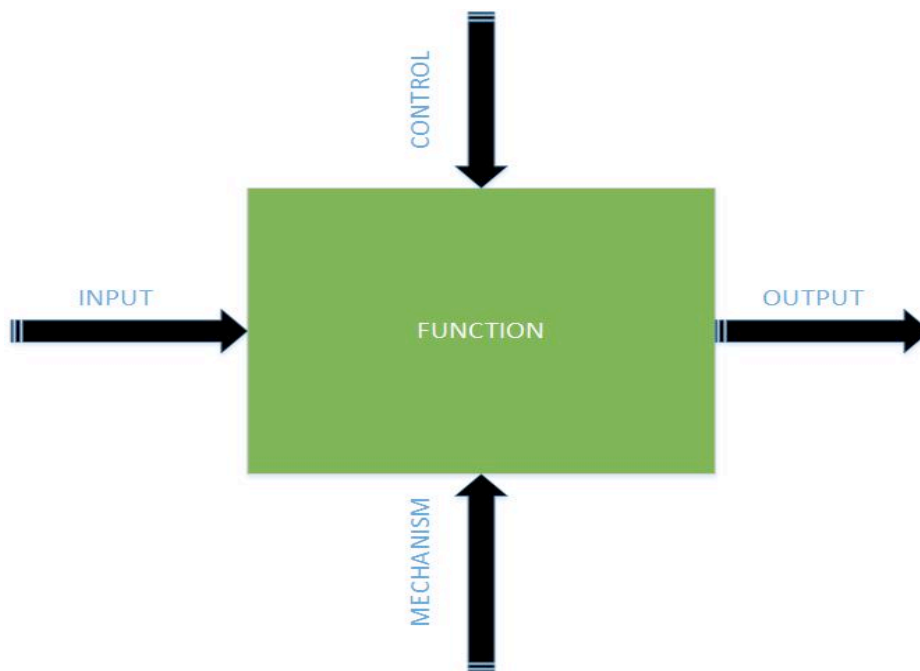


Figure 1. The IDEF0 process, derived from Soung-Hie and Ki-Jin (2000)

According to Soung-Hie and Ki-Jin (2000), 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 be about the post-contract cost controlling techniques in Nigeria. The aim of this study is 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 will be evaluated.

1.1 Post-contract Cost Controlling Procedure in Nigeria

Post-contract cost control starts from the initial budget that has been planned. Interim valuation follows this at the construction stage. Contractor or client's cash flow is prepared to monitor the project finances to ensure profitability (Sanni and Hashim, 2013). Other techniques used in monitoring construction cost during execution are earned value analysis (Hunter et al., 2014). New techniques involving intranet-based cost controlling system has 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). Ashworth and Perera, (2015) noted that 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 according to Ashworth and Perera (2015) is detailed as follows:

- 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*
- 4) *Final account, the agreement of final certificate and the settlement of claims.”*

The choice of a method of controlling the cost of a project during the post-contract stage depends on the contractor's selection method; 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 using literature will be explained in Table 1 below.

Table 1. Post-contract cost control techniques identified

| S/N | POST-CONTRACT COST CONTROLLING TECHNIQUES | REFERENCE |
|-----|---|---|
| 1 | Cash flow | Ashworth and Perera 2015; Sanni and Durodola, 2012; Sanni & 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 & Lin, 2008; |
| 12 | Site meeting and post-project reviews | Ankur & Pathak, 2014; Leu & 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: Omotayo & Kulatunga, 2017)

1.2 Improving Post-contract Cost Controlling Techniques using Kaizen Costing

The word "continuous improvement" or kaizen has become common in many organisations in the world. Contrary to the belief of many authors that kaizen started from the Toyota production system (TPS) along with lean production; Shang and Pheng (2013) argued that kaizen started from the United States when the government started the "*training within industry*", program during the World War II, before it was brought to Japan. Continuous improvement is not only relevant to performance management but also production management to great corporations and Small and Medium Enterprises (SMEs). Lean thinking and continuous improvement have become a subject which many organisations have harnessed as a tool for improved performances in all divisions. Koskela and Ballard (2012) argued that failure to leverage the concept of product in management has led to a lot of 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 the academia. The concept of lean production has significantly improved the cost, quality, client satisfaction and construction project delivery (Sacks, Koskela, Dave, & 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 ac-principle of kaizen. According to Puvanasvaran et al. (2010), another approach to kaizen costing involves the Plan-Do-Check-Action (PDCA) process. This process includes seven stages which are:

- 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) The organisation of the project team to brainstorm on 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;
- 7) Following up with the implemented plan require a checklist sheet, employees, the top management.

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

2. RESEARCH METHODOLOGY

The survey strategy was used to collect data from eighty-three (83) construction companies in Lagos, Nigeria. The company responded with one hundred and thirty-five questionnaires out of two hundred and fifty (250) questionnaires which were distributed to the quantity surveyors and project managers in these small and medium scale construction companies (SMSCC). The Kendall W test was used to rank these post-contract cost controlling techniques afterwards. Kendall W test is a non-parametric test. According to Legendre (2005), “*Kendall’s coefficient of concordance (W), is a measure of the agreement 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 is compared each variable as a pair to rank the most important variable. Mehta and Patel (2012) noted that 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). The author 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 for 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 creates more success when implemented. The techniques that produce the desired results when required is the most useful technique. Therefore, these techniques have more impact on the entire construction project during the execution phase. The most important post-contract cost controlling is one, which cannot be left out during post-contract cost control activities. These techniques are processes which the cost or project manager might always have 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 it is 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 this type of organisations based on the respondents' perception towards 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 is to assess the most efficient post-contract cost controlling techniques and also consider what small and medium scale construction organisations in Lagos are using. The results of this test assisted juxtaposing the present level of 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 effectiveness test is to provide a clear view of ingredients for a framework required for the implementation of kaizen costing in small and medium scale construction companies in Nigeria.

2.1 Effectiveness of Post-contract Cost Controlling Techniques

From the chart below, the techniques, which involve monitoring material cost ranks the highest with a value of 11.33, interim valuations, is perceived to be the second most effective with a value of 10.98. The use of 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 has a value of 10.61 and 10.41 respectively. They both 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 7.86, 8.09, 8.4 and 8.4 respectively.

The degree of agreement of this ranking Kendall's W is given as 0.05. Kendall's W value is always between 0 and 1. 0 indicates that there is no agreement between

the respondents, while 1 indicates perfect agreement (Pallant, 2009). The respondents' position on each of the post-contract cost controlling techniques is not in complete agreement with each. The respondents have divergent opinions concerning this question. The result implies that the respondents have varying views on the subject. Nonetheless, there is a significant association between the post-contract cost controlling techniques and the respondents.

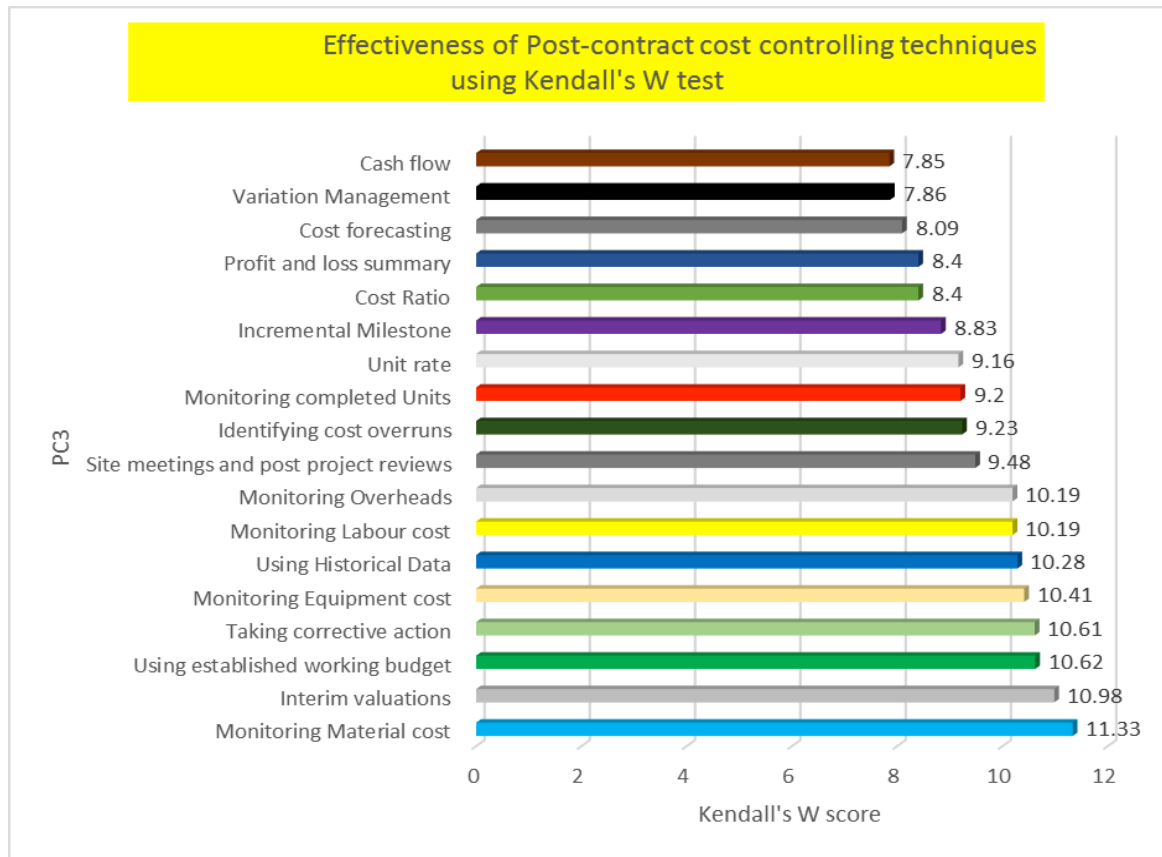


Figure 2. Effectiveness of post contract cost control bar chart

The respondents prioritised these post-contract cost control procedures as listed in the bar chart 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: Omotayo & Kulatunga, 2017)

2.2 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 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 to the 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.

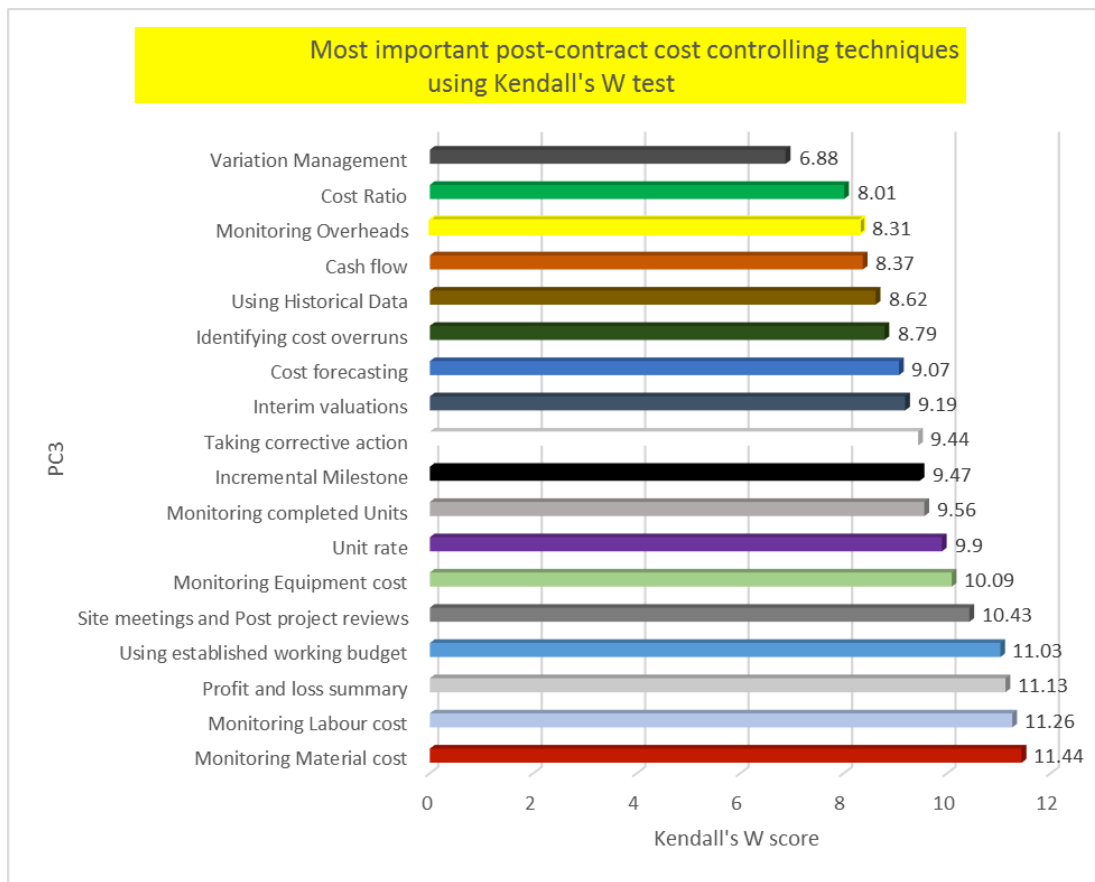


Figure 3.Important post-contract cost control techniques presented in bar chart

The Kendall W score of 0.043 shows an insignificant level of agreement for the most important post-contract cost controlling techniques and the respondent's ranking 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: Omotayo & Kulatunga, 2017)

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

3. 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 evaluate the level of agreement between the respondents, and this was analysed in figure 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 techniques and most important techniques. The most effective and most valuable techniques were identified as monitoring material cost. Cash flow was ranked lowest as the less efficient technique. Variation management is at the bottom of the most important technique. Using working budget during the construction process was ranked second as the effective technique. The bill of quantities according to Rad (2002) and Oyedele (2015) have a lot of 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 step of post-contract cost control as being monitoring and interim valuations, cash flow, monthly statements and issuing final certificates as the major steps for post-contract cost control. The techniques were not highlighted. Monitoring cost involves performance metrics (Oyedele, 2015), cost controlling activities depends on 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 you cannot control cost but only monitor what is going on during construction and take corrective actions. 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 bill of quantities.

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

Kaizen costing pertains to reducing expense during construction and maintaining quality for maximum profit and client satisfaction (Míkva et al. 2016; Knechtges & Decker 2014; Radharamanan et al. 1996). Therefore, the controlling activities on a site based on the techniques should include the principles plan-do-check-act. The plan-do-check-act as explained in the section will require one of the professional stakeholders to be activity involved in the PDCA process from section 1.2. 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.

3.2 IDEF0 process for post-contract cost control process

The IDEF0 is a modelling technique for process improvement. This model has been explained in section 1.0. 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 mobilisation fee has been paid to the contractors, the construction process commences. This process makes use of the working budget. The overall, desire of the contractor is to make the 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 the standard for construction. Interim valuations are conducted at intervals based on the Gantt charts or program of works. The units completed based on the tenders sums are sent to the client quantity surveyor for interim payments. This process has to consider the overhead expenses which will be monitored. Some of the overhead expenses will be for water, access road, electricity, sanitation, office overheads such as stationery, tables, chairs and other things associated with the preliminary items of work. The elimination of unnecessary activities and waste in the preliminary item of works are very necessary. PDCA is implemented at this stage. An employee may be appointed as a supervisor to focus on this process for timely 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 plants, labour and materials. The contractor quantity surveyor has to reduce and maintain the sub-contractors' quotations negotiation skill are required in this case. This consultation 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 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 very crucial for kaizen costing implementation. Overhead cost relating to material, labour and plants may be reduced continually for the attainment of 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 changes the design. Variation management and financial constraints on the path of the client may lead to dispute, cost overruns and project delays. In Nigeria, variation and have caused many projects to be abandoned. Therefore, the quantity surveyor and project manager (who may be an architect) need to work together quickly to resolve variations. 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 slight overrun in the budget. Nonetheless, most projects involving kaizen costing during the production phase has always experience increased profit, project completion on time, quality delivery, satisfied client, improved competitive advantage and project performance.

4. CONCLUSION

The findings showed that the monitoring cost of material is the most effective and important technique on site. Monitoring 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 there is where the profit lies. Monitoring of labour rates on the site is also very essential. The prices of materials and labour may vary from state to state in Nigeria. However, this study was based in Lagos Nigeria where the price is a bit stable. The cost of building materials for building construction may fluctuate during the duration of the project. Building material supply is also connected to many critical success factors which may be investigated for further studies. These factors are construction business and ethics. Many fraudulent practices go on during development activities in Nigeria, and this includes bribery, the kickback of fund and inflation of prices, which will affect 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 from the planning phase. These errors are carried over to the execution stage. Nonetheless, 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 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 be existing in SMSCC in Nigeria. Therefore, the third objective investigated the presence of kaizen in SMSCC.

IDEF0 has a way of identifying the primary processes which may assist the quantity surveyor or project manager 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 may look at the cost implications of having this type of framework for PC3.

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