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DESIGNING A CONCEPTUAL COST ESTIMATION DECISION SUPPORT SYSTEM (CCE-DSS) FOR PUBLIC PROCURING ENTITIES IN NIGERIA

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ABSTRACT: The growing complexity of construction projects, public demand for accountability and daunting pressures on meagre budgetary allocations and quest for reduction in transaction cost have continued to mount pressure on in-house cost experts to devise scientifically provable design for conceptual cost estimates (CCE) of construction projects. By combining historical data with predictive analytics, proven benefits abound for optimizing cost estimation for construction projects at the preliminary stages. The application of decision support systems (DSSs) in Conceptual Cost Estimation (CCE) is a good platform where a data-sensitive and conducive environment can support construction project budgeting process and enhance decision-making on competing project alternatives and similar future projects. In a build-up to the development and design of a support system architecture for CCE-DSS, a pro-foma is developed from a Qualtrics platform to collect data from new construction projects with similar attributes. The system analyzes data by a predictive analytic model and displays results graphically. The analysis of data from selected ministries, departments and agencies (MDAs) were compared in a cross-matrix fashion to draw inferences. This paper sets a platform for predicting the acceptance of DSSs in public organizations in Nigeria and adds to the body of knowledge on conceptual cost CCEDSS design, by proposing the development of a DSS architecture for construction cost estimation in public organizations. It is concluded that the application of DSSs for CCE in public organizations have many promising levels of accuracy. The results of the study can be improved upon by employing hybrid multi-criteria decision-making methods (MCDM) in the system architecture and increasing the number of public organizations to make for a more generalized conclusion.

Keywords: Conceptual Cost Estimating, Decision Support Systems, Public Organizations, Nigeria

INTRODUCTION

According to Morledge & Smith (2013) contract transactions in construction generally involve clients with limited experience of engaging with the sector. Public organizations in Nigeria depend on external consultants as well as in-house cost advisors for preliminary estimates of construction projects, with published cost data commonly used as referenced input. The professionals often rely on intelligent software to solve the emergent complex problems which are generally multi-faceted. According to Fayoumi & Loucopoulos

(2016), 'intelligent software' have emerged as an avenue by which organizations can respond to changes in their system possibilities for new models in a proactive manner. Therefore, the development of software systems demands analysis, design and implementation paradigms that recognize the need for 'co-development' of the systems with enterprise goals, processes and capabilities. For public organizations, the adoption of these systems must not lose sight of the enabling public laws, transparency and the attendant oversight mechanisms (Tabish & Jha, 2018), as well as maintaining professionalism (Maestripieri, 2016; Mrope, 2017; Perrenoud, Lines, Savicky, & Sullivan, 2017).

Popescu, Phaobunjong & Ovararin (2003) argue that many companies use published databases to predict future cost increases in addition to reporting past performance. Therefore, decision makers in client organizations must adopt a mix of learning behaviors constituted by a semi-automatic accumulation of experience and deliberately invest in knowledge articulation and codification activities. Sadly, Chenoweth, Dowling, & Louis (2004) berate DSS users' reluctance to expend efforts on using existing models as they generally favor less effortful strategies. Ahuja, Yang, & Shankar (2009) also condemn slow adoption Information and Communication Technology (ICT) in the construction industry, as concurred in (Yap, Chow, & Shavarebi, 2019), especially in the area of CCE.

Conceptual Cost Estimating (CCE)

According to Ashworth & Perera (2015), there is a trend towards modern designs and new techniques, materials and methods of construction. The designer is able to choose from a far wider range of products and this has produced variety in construction. The traditional estimating methods are unable to cope with these circumstances to achieve value for money and more balanced designs. Therefore, an increase in volume of information required for preliminary estimates and outmoded fashion of manual computation of cost estimates have generally necessitated the adoption of more efficient approaches in conceptual cost estimating (CCE) using system aids. Rourke & Cronin (2016) recount the strategic importance of CCE on project planning as an essential part of construction project planning.

CCE paradigm has evolved since the 1990s when it emerged as a novel thrust in preliminary forecast of construction projects cost (Rad, 2002). CCE is conducted at the inception of the project, when the owner typically has greater influence and lower sunk costs, than other estimating types on later phases (Gibson Jr, Kaczmarowski, & Lore Jr, 1995). CCE forecasts the approximate costs to evaluate the economic feasibility of proceeding with the project. CCE is prepared at nearly one-third of the time for completed design. To initiate a project, public organizations generally conduct owner's study including a technical and an economic feasibility study of the proposed construction project (Hughes, Champion, & Murdoch, 2015). There is however, difficulties in determining the accurate project costs at the earliest phase of a project. But a conceptual cost estimation (CCE) is a part of an economic feasibility study. As a front-end decision in construction projects, CCE is needed to determine the feasibility of projects. At the later phases, designers and constructors will need CCE for financial evaluation of alternatives and scrutiny of an initial budget. The effectiveness of a CCE method will then depend on efficient utilization of limited information under constrained time and resources.

Direct Labour Procurement of Construction Projects

According to Osanyinro & Aghimien (2017), procurement methods determine the overall framework and structure of responsibilities for participants in a contract process and thus, a key factor contributing to overall project success. Public procuring entities are observed to engage in perfunctory choices of procurement methods, based largely on familiarity with a particular procurement method rather than an informed choice based on project needs assessment as concurred in Iyagba & Idoro (1995). Direct labour is still used by government even after the promulgation of the public procurement act, 2007 (Idoro, Iyagba, & Odusami, 2007) for projects that are within acceptable threshold, essentially rehabilitation and maintenance works. Direct labour demands extensive use of in-house professionals and craftsmen in the design and execution of construction projects. Direct labour has been criticized as wasteful because of proportionately high overhead costs associated with the method, waste inherent in it is largely exacerbated by the absence of a reliable CCE. Ebekozien, Duru, & Nwaole (2017) in their conclusion, acknowledged the encumbrances faced by the in-house professional in construction projects and emphasized the need to engage them in order to enhance cost savings in projects. This early engagement of professionals entails their application of conceptual cost estimating (CCE) responsibilities which is still laden with the non-availability of scientifically verifiable support systems.

LITERATURE REVIEW

In a cost model developed for a reliable sum insured, Pieterse (2018) proposed an estimating method that would place residential property owners and insurance industry players in a much-improved situation when insurance claims occur and lessen potential financial damage. The model was based on small but diverse sample. Test cases were deficient in achieving higher accuracy and reliability for want of database that is adequately populated with sufficient cost information. The peculiarity of construction projects in a logistically challenging environment like Nigeria (Dania, 2016. pp. 210) and its related activity has continuously served as an obstacle to generating accurate and reliable CCEs. ICT sectors has advanced in technology and has continuously enhanced the production of estimates that are mostly inaccurate. Some of the obvious challenges with existing CCE (Ashworth & Perera, 2015) are:

i. A general trend towards greater cost-effectiveness necessitating the scrutiny of construction costs not solely in the context of initial costs but in terms of its whole-life or total-cost considerations.
ii. Overwhelming preponderance of the requisite tools and techniques required to produce estimates with greater accuracy for cost professionals with the means of control of costs which generates a greater expectation of achieving better cost control in construction projects.
iii. Constructor's interests have in real terms been reduced considerably during the past decade. This has resulted in their neglect of cost-factors in an attempt to redress possible increases. The elimination of waste, and more emphasis on the use of the world's scarce resources is increasing. This has necessitated a desire for improved methods of forecasting and control of costs.
iv. Meagre budgetary allocations and growing need to manage limited resources has generally produced a shortage of funds for capital purposes and construction in general. This is further exacerbated by high inflation and interest rates, resulting in the costs of construction increasing to very high levels. Although the relative costs compared with other commodities may be similar, the apparent high costs have resulted in greater caution, particularly on the part of clients.

The application of computers in developing CCE has transcended generations in the construction industry. Leung, Yu, & Liang (2013) report the development of a FORTRAN mainframe computer program that integrated cost, time and resources in earlier research. Their program revealed the effect of decisions about the work on cost and time by using what-if analysis. Earlier research (Kouskoulas & Koehn, 1974) discussed analytical models for conceptual cost estimating by applying six (6) variables in a linear equation. Similarly, many analytical methods that apply historical data have been developed to improve estimation for building projects. Research have used computer programs and complex analytical techniques in CCE since the 70s. Raftery (1987) reported the use of simple cost estimation techniques widely by construction managers who rely on their knowledge and experience like square foot methods for CCE.

Kim, Seo, & Hyun (2012) develop approaches that generally apply more complex methods and a large volume of data using computer technologies and mathematical programming techniques. Some common methodologies include case-based reasoning (An, Kim, & Kang, 2007), data envelopment (Cheaitou, Larbi, & Al Housani, 2018; Taylor, Yang, Wang, Wang, & Ma, 2015), data warehousing (Ahmad, Azhar, & Lukauskis, 2004; March & Hevner, 2007), regression analysis, multi-linear regression (Yang, Liao, & Wayne Wei, 2014), artificial intelligence (Irani & Kamal, 2014; Tang, Leung, & Wong, 2010), artificial neural networks (Al-Sobiei, Arditi, & Polat, 2005), analytical hierarchic process, fuzzy logic, fuzzy set theory, PROMETHEE, VIKOR as well as support vector machine (Ameyaw & Chan, 2016). Multi-criteria decision analysis (MCDA) has emerged as a branch of operations research that is aimed at facilitating the resolution of these issues (Kiker, Bridges, Varghese, Seager, & Linkov, 2005; Sharma, 2015). Since then, a great variety of multi-criteria decision making methods (MCDM) have been developed to tackle them under different circumstances and fields of application (Jato-espino, Castillo-lopez, Rodriguez-hernandez & Canteras-jordana, 2014).

Decision Support Systems (DSSs)

Pick & Weatherholt (2013) define a (DSS) as "a computer-based system that supports choice by assisting the decision-maker in the organization of information and the modeling of outcomes." A DSS is most useful in the context of semi-structured and unstructured problems. One definition of DSS as an abstract description of the real world aimed at simplifying a world of complexity is still relevant today as DSS architecture are generally concealed in computer applications and using suitable user interface (Omar, 2012). Power & Sharda (2007), classify DSSs into: (1) communication-driven DSS handling information sharing between a group of people, that is, facilitating community of practice); (2) data-driven DSS (using internal or external company data in a time-series basis); (3) document-driven DSS (handling unstructured information); (4) knowledge-driven DSS (handling information by establishing a training database and rules); and (5) model-driven DSS (using data and parameters to aid a decision-making process). These all are essential architecture upon which systems are generally developed.

The followings researches have demonstrated the application of decision support systems (DSSs) in the built-environment research; Structure-driven DSS for site selection (Ahmad, Azhar, & Lukauskis, 2004; March & Hevner, 2007), procurement strategy (Banwo, Agyekun-Mensah, & Arewa, 2016; Kumaraswamy & Dissanayaka, 2001); enhancement of Construction Claims Management (Banwo, 2016); tourism destination (Baggio & Caporarello, 2005); materials selection (Pearce, Hastak, & Vanegas, 1995); deterministic contractor selection (Semaan & Salem, 2017); model-supported, cost-based decision making for interior designs (Lee, Lee, & Kim, 2010); Group Consensus (Ben-Arieh & Easton, 2007) and resource leveling in construction (Wang, Yu, Yang, Lin, & Lee, 2013). Generally, model driven DSS (Power & Sharda, 2007) have been rampant. But experts have generally been reluctant in applying the DSS for the want of justifying the rigors of computation. Pick & Weatherholt (2013) explained that two essential ways that a DDS is distinguished from other computer-based systems include; a focus on decision-making and an interactive usage mode requiring both the system and the decision-maker to contribute to the decision-making process.

Other studies like 'Integrated approach, with consideration for potential application of the internet of things for the built environment' (Kaklauskas & Gudauskas, 2016; Ghodsypour & Brien, 1998; Turban & Watkins, 1986), study of model-driven by teams (Walraven & de Vries, 2009), support functions (Alyoubi, 2015), agent-enabled, service oriented venture (Dong & Srinivasan, 2013), process-focused approach, as in construction tendering process (Mohemad, Hamdan, Othman, & Noor, 2010), are important examples that have continued to recognize the relevance of DSS on construction projects and conceptual cost estimating in the construction industry. But DSS development is still reported in extant procurement literature as nascent (Chau, Moynihan, & Vereen, 2018), leaving its relevance for practical application as a vulnerable concept that may be difficult to receive wider acceptance in the construction industry.

Public Construction Projects

Every project is unique with risks scattered and embedded in the different phases of its development. Therefore, having poor quality and value of information will lead to greater uncertainties that further make the decision environment even more unstructured (Kiker et al., 2005). These also makes it more difficult for stakeholders (e.g. designer, the client, an engineer, and a surveyor) to take decisions during the design and planning stages (Tang et al., 2010). Many real world decision problems like conceptual cost estimates combine qualitative and quantitative criteria. Structures that combines alpha and numeric criteria, alternatives or variables have difficulty in modeling real world problems because of conflicting interests in human actions (Bobar, Mandić, Delibašić, & Suknović, 2015; Liu, Huo, Liao, Gong, & Xue, 2014; Liu et al., 2017; Plebankiewicz & Kubek, 2015) . Information gathered in aiding decision-making process can be structured (e.g., in a form of a document) or unstructured (by the word of mouth). Despite the presentation of a multifaceted approach, an unbiased choice of an individual is key to the success of a decision-making process. This narrative is further compounded by the reluctance of public organizations to adopt new technology in spite of their proven benefits (Malek & Gad, 2017). Pearce et al. (1995) agree that construction managers do not always use DSSs extensively. Also, the design of DSSs have recently emphasized web enablement as the next step in design improvements, but Dong & Srinivasan (2013) argue that this fails to address the key notion of adaptability in the support for decision makers. Rather than focus exclusively on automation in decision making, they opine that it is also necessary to pay attention to the interplay between decision makers and organizational processes.

RESEARCH METHODOLOGY

In developing a prototype DSS for estimating costs and performing data analysis among alternative projects at the conceptual phase of public construction projects, public procuring entities in Nigeria were selected randomly for this study. This was to provide estimators and executive managers alike with crucial data and valuable information during the decision-making process on capital budgeting and capital allocation to publicly procured construction projects. Roofing construction is the only work section considered in the conceptual cost DSS design. The 'Roof' element identified from ten (10) number items in work breakdown structure (WBS) selected from twelve (12) number Federal Government MDAs whose operational headquarters are in Abuja - Nigeria. The MDAs were carefully selected based on the volume of construction and infrastructure works executed by them in the last five years through direct labor. Data used in the conceptual cost estimation was collected from Project Departments through a survey by a Qualtrics Software (QS). The MDAs referred in this paper as a single organization in their true meaning, guided mainly by the same procurement laws (PPA, 2007) and a homogeneous public policy drive. Although organizational peculiarities exist in the MDAs, the methods, approaches and general characteristics are similar. This therefore minimizes the limitation associated with using single organizations as conceptualized in Chau et al. (2018).

Feasibility of Data for the Study

An essential component of a reliable research is the quality of data on which the analysis is based. A data feasibility study is required to investigate the potential of data prior to initiation of this paper. Very relevant data include language, mathematical, or symbolic representations of people places, things, and/or events. Similarly, information result from filtering, processing, and formatting of data in a way that increases the level of pertinent knowledge for the recipient. Cost advisers of the selected MDAs were contacted and interviewed with the sole aim of ascertaining end user requirements for CCE decision support systems. The near absence of database for cost estimating in the MDAs constitute a major hindrance to the study, as public officers were also generally reluctant to divulge information, especially on direct labour construction costs.

Data Entry Form

A data entry form was developed to collect potential data for the estimating model. After studying some potential methods, the Qualtrics software was chosen to develop the survey entry form. Qualtrics is an online survey tool which has a data entry function integrated with a distributing function

(Qualtrics, 2012). Participation can be monitored by Qualtrics users, send invitations and reminders, display survey results graphically and statistically in real time, and export raw data in a variety of formats (to XML, HTML, CSV and SPSS, and other popular statistical packages like Path analysis, neural networks, SMART PLS). Based on executed construction works by MDAs, two different types of data entry forms were developed for Quantity surveyors and Architects who provide construction cost data and detailed design respectively. A survey of roofing sections created on the Qualtrics include 45 questions. Each question corresponds with a variable presenting a characteristic of the respective project. The questions were created based on a set of five (5) main criteria:

i. Availability and Collectability: The data relevant for the analysis should be available and collectable. For instance, confidentiality of cost information like profit, overhead as well as transaction cost are not readily available and collectable.
ii. Classifiable: Data with similar characteristics should be classified under a category. For example: asphalt shingles and metal shingles can be classified under the shingles and shakes variable of the roof material.
iii. Terminology: the terminology and technical acronyms used in the entry forms has to be consistent. For example, "In-house cost" could be confused with "Budgetary provision" or appropriation. Clarity is enhance by the use of relevant instructions.
iv. Level of details: For all relevant variables, the number of levels is very important. Chau et al. (2018) opined that a low number of levels may result in lacking information and under fitting the model. However, a high number of levels will result in overfitting the model and result in difficulty of computation to the estimators. This may provide overdetailed information.
v. Officially recognized sources: Potential sources were selected to facilitate development of the survey questions. In the UK, the Building Cost Information Service (BCIS) is useful for building prices information (Cartlidge, 2011). The National Building Code (FGN, 2006) and published data from the NIQS quarterly are useful reference materials. There is however the challenge of connecting with e-version of the published cost information from the available portals

Profoma, Revision of Data Entry Form and Investigation of CCE Process

Feedbacks from quantity surveyors and architects aided in reversing the data entry form. Personal interviews were conducted with cost advisors currently engaged in renovation works that encompass roofing. Subsequently, current practice in CCE decision-making was an investigated. General practice of CCE is in its infancy as acknowledged in literature and the involvement of built-environment experts as well as administrative staff is suffering diminution in the MDAs. This approach is useful in harmonizing the underlying constructs for the purpose of coherency in the articulation of the current practice, revealing the industry's CCE culture.

Data Collection

Data was collected, refined and validated by obtaining an industry consensus on the relevance of the data to a CCE process (Chau et al. 2018). A similar approach is adopted by reviewing the cost information obtained from acceptable sources in order to advance for wider usage in the public procuring entities. The harmonization of the data also encourage buy-in by the target end-users of the DSS as advocated in Chenoweth et al. (2004).

Predictive Analytical Model

Artificial Neural Network, Regression model, decision tree, support vector machine, data warehousing and fuzzy logic are investigated in building the model. The model constitutes the system architecture which is chosen based on the form of data, source of the data, accuracy, model complexity and user requirements. In this paper, a mathematical model that draws strength from a quantification power is used for the proposed system.

DSS Ontology

Research have decried the challenge of integrating and transforming the entire tendering processes into electronic or digital form by using web-based technology. The reasons is that the use of unstructured documents either in hard copy or digital form could not be neglected in daily business processes especially for recording, authentication and information exchange purposes. The difficulty of automatically converting unstructured data to structured format data for input in decision-making processes is also acknowledged.

Extracting and representing information in machine readable formats becomes obviously important.

Determination of DSS Architecture and IS/IT Infrastructure

Decisions are also reached through collaborations and consensus of the cost advisors. The application of hybrid multi-criteria decision making (MCDM) tools proves to be highly effective (Jato-espino, Castillo-lopez, Rodriguez-hernandez, & Canteras-jordana, 2014; Yang, Liao, & Wayne Wei, 2014). Common 'hybridizers' are the Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) (Behzadian, Kazemzadeh, Albadvi, & Aghdasi, 2010) and the fuzzy logic sets (Dissanayake, 2017; Singh & Tiong, 2005). Based on the essentials of a typical DSS schema; knowledge source, knowledge base and the inference engine (Irtishad Ahmad et al., 2004; Mohemad et al., 2010), the identification and application of suitable architecture will prove to be more sufficient. But the user interface subsystem is incorporated in the design in order to conceal complex relationships between data and make system use simple (Omar, 2012). Figure 1 is a summary design of the DSS adapted from Chau et al. (2018) which shows the algorithmic linkages on a CCE flow chart.

Using a Software Application System (SAS) Platform.

A software application system (SAS) is proposed to create a framework for the user interface. The SAS encompasses the System Component Language (SCL) which is used to monitor the framework and run SAS procedures embedded with predictive analytics models. Artificial Neural Network is proposed for converting raw data which is stored in Spreadsheet files or a database management system. It can be imported to the system via a SAS import procedure. Microsoft excel is a relatively simple in application. Researchers have reported the reluctance of public sector employees in using ICTs. The immense benefits of generating useful data from unstructured cost information and aiding cost advisors/estimators to easily manipulate raw data without requiring in-depth knowledge of using SAS is considered to be a prime motivator for adoption.

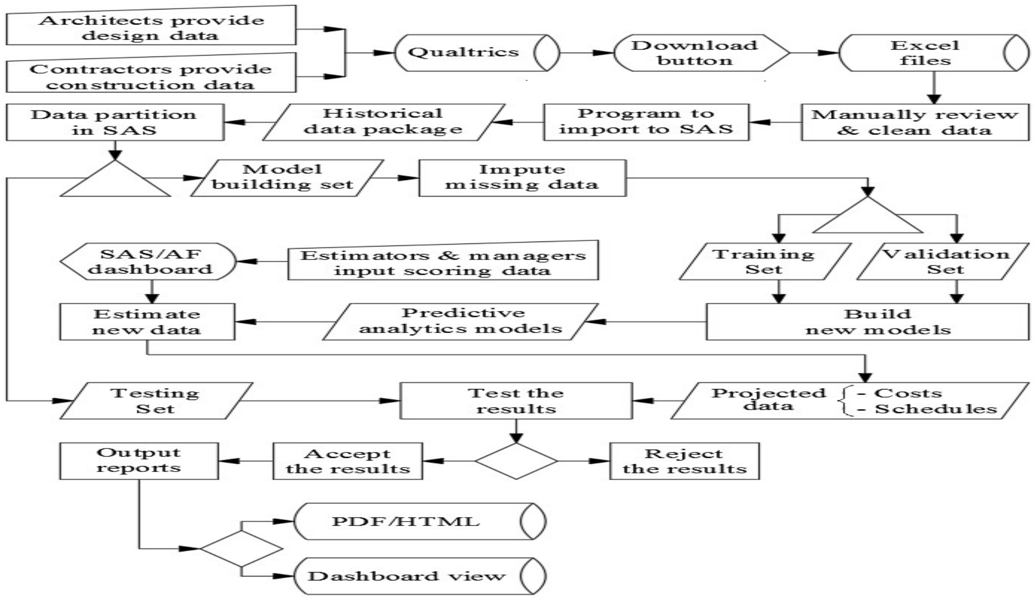

Figure 1. Proposed CCE-DSS Flow Chart (Adapted from Chau, Moynihan, & Vereen, 2018).

System Application and Programing

The system architecture is essentially important for the computation of the conceptual cost estimates. They form the major components of the Statistical Analysis System which is a group of analytical software developed by system analyst with specialty in the inference engine. This contains a data management facility, programming language and data analysis and reporting utilities which is considered as the foundation of the system. The creation of a portable system is therefore possible with data entry (input point). The system ontology which lays bare an entry location/position simplifies the system dashboard that is simple and easily adaptable by the conceptual cost estimator. Raw cost data are inputted into the system and outputs are generated in the form of articulated information which are easily interpretable by the estimators on the basis of which project decisions are taken.

System Validation

DSS can be operated alongside the existing estimating system. The output and performance of the two systems are reviewed and analyzed. In addition, a test data set will be partitioned from the main data set and preserved for system validity phase. According to some researches (Kim et al., 2012; and Douglas et al., 2008), the performance of a predicting model in decision system can be accounted for by the mean of error (%). Chau et al.'s (2018) mean error formulae (equation 1) is used to verify and validate the system model.

$$\text{Mean of Error (\%)} = \frac{1}{n}\sum_{n=1}^{\infty}\left(\frac{Actual\ Cost\ -Predicted\ Cost}{Actual\ Cost}\right) x\ 100\%$$

……..Equation 1

Where: n is the number of observations in the test data set.

∞ (Infinity), signifies that number of entry can be 'infinity defined'

Validation is to ensure that the consistency in data is observed. The limitation in this study is that in practice, the rigor of computation may discourage the cost advisors from applying the support system in conceptual cost estimation. However, the validation in this study is enhanced by incorporating the project specifics as well as generally large data entries.

CONCLUSIONS

This paper deductively adapted the innovative proposition in a recent research for replication in Nigeria. In a generally qualitative fashion, through an empirical consideration of relevant data from a selected MDAs, a CCE-DSS development was advanced. 'Roofing' was considered to be the commonest item of work in the sample of bills of quantities used for the case study. As a reoccurring work section in the WBSs from public projects executed by direct labor, the data collected were relatively consistent. Construction projects executed by direct labor in selected MDAs require conceptual cost estimation to support decision making in project budgeting. The validation technique in this study accommodates for the computation of larger amount of data as compared in similar works. The development of the decision support system is ongoing. This paper presents the design for a prototype decision support system that potentially optimizes the accuracy of a conceptual cost estimates in Nigerian public organizations.

The SAS software is chosen to be the system platform where the technical computations are concealed. This system will improve the accuracy of CCE compared to current practice in the public organizations. The main focus of this paper is on building a predictive model with a graphical user interface. Data is collated manually from reputable cost information sources and converted to system (SAS) file format. SAS data files are stored in the data management system where analysts can frequently update them. By using this system, deviations from target can be more easily verified with enhanced CCE accuracy for public construction projects in Nigeria.

RECOMMENDATIONS FOR FURTHER STUDIES

The development of CCE-DSS can be further extended in future researches to accommodate qualitative data. In addition to ANN system architecture, the integration of Fuzzy Logic sets or suitable MCDM with adaptably provable positivity can be utilized. This option minimizes the unwanted influence of subjectivity in human thinking, economic, political, social as well as environmental factors on cost computations. Preference elicitation model (Yang et al., 2014), is also a formidable platform where subjectivity in the CCE decision making could be optimized with the consideration of management as users of estimates at the strategic level of the public organization. Therefore, developing a decision support for cost advisors in the public sector using an iterative framework is a possible research area that is worth exploring. Moreover, when the internal and external factors like inflation and other attributes of cost are exceptionally large, the setting with large scale data space will require more advanced methodical enquiry.

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