MODELLING COST AND TIME PERFORMANCE OF PUBLIC BUILDING PROJECTS IN A TERROR IMPACTED AREA OF NIGERIA

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ABSTRACT

Examine the impact of construction cost-and-time-influencing factors on the production performance of public building projects in north eastern Nigeria and whether a predictive model could be devised in assessing this impact. The global poor performances of construction project cost and time, coupled with a dearth of studies into using machine learning systems as artificial neural networks for advanced cost and time impact predictions, has made researching into construction project performance imperative. Moreover, the Boko Haram insurgency in Nigeria's North East geopolitical zone intensified the disruptions of construction site programmes with consequent cost increases. Therefore, prediction and performance measurement tools for construction project cost and time can possibly be developed from the examination of data on initial contract sums, estimated construction duration, final cost, actual construction duration, and the influence of cost and time driving factors on public building projects in north eastern Nigeria. The research objectives include an assessment of the factors influencing the cost and time performance of public building projects in north eastern Nigeria and determination of the cost and time performance of selected public building projects in the study area. Others are the development of models for assessing the impact of cost and time influencing factors on the performance of cost and time in public building projects in the study area. Lastly validation of the developed cost and time performance impact assessment models of public building projects in the study area. A quantitative research approach that employs a questionnaire survey was adopted in sourcing primary and secondary data from purposively sampled construction industry professionals. The study used one-way between-groups Analysis of Variance with a post-hoc test, one-way repeated measures Analysis of Variance with Wilks' lambda tests, multiple linear regressions (MLR), Factor analysis (FA), and Artificial Neural Network (ANN) to analyze the data collected. This data was about initial contract sums, estimated construction duration, final cost, actual construction duration, and the influence of the identified driving factors on public building projects, completed between 2012 and 2017.

The study found that the mean percentage cost overrun of the projects studied decreases from uncomplicated projects to moderately complex projects; and increases from moderately complex to largely complex projects. Also, the mean percentage time overrun decreases with increases in project complexity. The significant cost influencing factors are the inexperience of the contract manager, payment delays to main contractors, unstable foreign exchange, variations to works, and corrupt practices. The time influencing factors include design errors, cash flow problems, payment delays to main contractors, contractors' improper contract knowledge, and delay in building plans and approval. These factors found in the study area were used to develop MLR and ANN cost and time impact prediction models. The developed ANN impact prediction models were validated and compared using previous similar studies in terms of relative absolute deviations and mean absolute percentage errors. The MLR models, although better than the ANNs in terms of mean absolute percentage errors and relative mean absolute deviations, it yeilded poor explanations of the variances in the dependent variables (impacts or overruns) by the independent variables (multiple influence factors). The alternative ANN impact prediction models' statistics are: (i) MAPE of the developed cost impact model prediction efficiency was found to be 93.54%. The Rel. MAD of the developed cost impact model was computed to be 1.46, in other words, plus or minus 1.46; (ii) the MAPE of the developed duration impact model prediction efficiency is 92.94%. The Rel. MAD of the developed duration impact model computed is 0.85, in other words, plus or minus 0.85. The ANN models compared favourably with previous similar studies in terms of relative absolute deviations and mean absolute percentage errors. The ANN’s capability of learning from examples represents an innovative approach to modelling. The study concludes that the developed ANN cost and time impact prediction models have the potential to aid the construction contractor in predicting the cost outcome of a project during the construction stage, by using the significant cost and time influencing factors. The study recommends that project managers, contractors, quantity surveyors, architects, builders and engineers should place priority on the significant factors identified in this study in their project planning, monitoring and control activities. Also recommended is the conversion of the developed models into Dashboards that construction professionals could use to promptly identify the factors influencing cost and time on construction projects, and to monitor performance.

DECLARATION STATEMENTS

I declare that all the information contained in this thesis has been collected and presented in accordance with ethical rules and academic conduct of the University of Cape Town. I hereby declare that this thesis signifies my own work which has never been submitted either in parts or whole for the award of any degree, diploma or any other qualifications, except where due acknowledgement has been made in the thesis.

Signed…. Signed by candidate

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DEDICATION

This thesis is dedicated to the loving memory of the faithfulness of the Almighty Jehovah-GOD in the name of our Lord Jesus Christ, His only begotten son who releases to His children from His storehouse of knowledge, wisdom, discretion and understanding. I bless His name for finding me worthy to be given the inspiration first to conceptualize the topic and the agents He (GOD) laid on my way that assisted me to pursue the study successfully. My prayer for my beloved grandchildren (Hezekiah Victory Ohiomah Ikechukwu Ihediohah, Promise Akachukwu McDonald Ihediohah, Emmanuelah Olohigbe Israel Oboirien, Uduigwomen Divine Israel Oboirien, Samuel Iswell Okhumeoya Israel Oboirien and their expected excellent younger ones) is that they will be part of Nigerians and Africans who will successfully occupy till when Jesus Christ comes, Amen. They shall not be delayed, even in the obstacles and hindrances they shall succeed more because Christ Himself overcame for us, Amen. Almighty God, please bless my faithful associate, Faith Anegbeje Atatah Usman Ohiomah Sekinetu Oboirien for the entire human race; she stood by me in questionnaire administration in the entire north eastern Nigeria.

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3 **Oboirien M. Ohiomah**, Abimbola, Olukemi Windapo & Odeyinka Henry (2017). A conceptual framework for modelling the impact of construction cost influencing factors on project cost using the artificial neural network. *Proceedings of the May 2017 EDMIC on the Sub-theme: Advances in Construction Management and Economics, Pp 419-427, Obafemi Awolowo University conference centre, Ile-Ife, Ife. Osun State, Nigeria.*

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List of abbrevations and acronyms

ACWP	Actual cost of work
AI	Artificial Intelligence
ANN	Artificial Neural Network
ANNM	Artificial Neural Network Model
ANOVA	Analysis of variance
AECOM	Architecture, Engineering, Consultancy, Operations and Maintenance
BAC	Budget at completion
BCIS	Building Cost Information Service
BCWS	Buget Cost of Work Scheduled
BMPIU	Budget Monitoring and Price Intelligence Unit (Due Process)
BOQ	Bills of Quanrtities
Bp	Back-propagation
BPP	Bureau of Public Procurement
Cidb	Construction Industry Development Board
CBR	Case Based Reasoning
CFC	Cost factor component
EAC	Estimate at completion
FA	Factor Analysis
FIFA	International Federation of association football
FUTY	Federal University of Technology, Yola
GDP	Gross Domestic Product
GMR	Group Mean Ranking
HN	Hidden Node
IBM	International Business Machines
ICS	Initial Contract Sum
M	Mean
MAE	Mean Absolute Error
MAPE	Mean Absolute Percentage Error
MASE	Mean Absolute Square Error
MAUTECH	Modibbo Adama University of Technology
ML	Machine Learning
MLR	Multiple Linear Regrssions
MLRM	Multiple Linear Regressions Model

MRA	Multiple Regressions Analysis
MSE	Mean Square Error
NITT	Nigeria Institute of Transport and Technology
NN	Neural Network
PCA	Principal Component Analysis
PLS-SEM	Partial least square structural equation modelling
PMBOK	Project Management Body of Knowledge
Rel.MAD	Relative Mean Absolute Deviation
RM	Malaysian Ringgit (Malaysia currency symbol)
SD	Standard deviation
SS	Sample Size
SME	Small and medium enterprises
SPSS	Statiscal Package for Social Scientist
SVM	Support Vector Machine
T	Tolerance
TFC	Time Factor Component
UAE	United Arab Emirate
UK	United Kingdom
USA	United States of America
VIF	Variance Inflation Factor

CHAPTER ONE: GENERAL INTRODUCTION

1.1 Introduction

The aim of this chapter is to provide a general introduction to the study. It begins with the background, the research problem statement and the research questions upon which the study is focused. The objectives which articulate the aim of the research, are outlined together with the research propositions. The significance of the study, overview of the research methodology, the anticipated contribution to the existing body of knowledge in the field of construction management and economics, the definition of terms used in the study, and the structure of the thesis are described in this chapter.

1.2 Background to the study

Project success is difficult to define because of the complexity and dynamics of the concepts of the project. Construction project success has been discussed by many researchers and until now, there is no accepted universal definition of project success. Nevertheless, Nguyen and Chovichien (2013) define construction project success as the foundation to manage and control the present, plan and orient the future project. While (Oyedele, 2012; Silva, 2016) define project success as the ability of a project to meet the planned cost, time, quality, safety and stakeholder satisfaction. Silva et al. (2016) identified ten success criteria for construction projects, which can be described as subjective and objective. They are Time, Cost, Quality, Safety, Client's Satisfaction, Employee's Satisfaction, Cash flow management, Profitability, Environmental Performance and Learning and Development. The first two factors – cost and time, in the context of this study are regarded as major success indicators of construction projects common to stakeholders (Ahsan and Gunawan, 2010; Ali and Kamaruzzaman, 2010; Assaf and Al-Hejji, 2006; Apolot et al., 2015; Atkinson, 1999; Bamisile, 2004; Chan et al., 2004; Dursun and Stoy, 2011; Kasimu, 2012; Le-Hoai and Lee, 2009; Mak, 2000; Oyedele, 2012; Shr and Chen, 2006; and Stojeetovic et al., 2014). The excess cost and time over the initial target are regarded as overrun. The term is defined as the excess amount of money or time over the initial contract sum or estimated construction duration (Avots, 1983; Chan, 2001; Divya and Ramya, 2015; Choudhury and Phatak, 2004; Himansu, 2011; Kaming et al., 1997; Raftery, 2003; Siemiatycki, 2009).

In the building and construction industry, final cost (actual construction cost or as-built cost) is the actual amount of money due to the contractor, certified by the prime consultant and consented to by the client as the cost of completed work. In all contract systems except fixed or firm price contracts for which the tender sum is not alterable, the final cost of construction is determined at project completion stage (Hammad *et al.*, 2008). Clients, contractors and other construction project stakeholders know that final cost may not be the same figure as the initial contract sum (Butler, 1988; Cantarelli et al., 2010; Gambo et al., 2012; Hammad et al., 2008; Hendrickson, 2008; Ugulu and Ikwuogu et al., 2011). The same is true of the variability between estimated and actual construction durations. Construction contractors are aware of the importance of completing projects within budgets of cost and time; this is shown using terms such as Budgeted Cost of Work Scheduled (BCWS) and Actual Cost of Work Performed (ACWP) in their operations monitoring books. BCWS is the monetary sum of the budgets for all work scheduled to be accomplished within a given time. It also includes the cost of previous work completed and addresses a specific period of performance or a date in time. A contractor reports the cumulative Actual Cost of Work Performed (ACWP) for the workdays that have been completed. Cost variance is the difference between the Budgeted Cost of Work Scheduled (BCWS) and Actual Cost of Work Performed (ACWP) (PMBOK, 2017). In other words, cost variability is the difference between cost incurred and the budgeted or planned amount of cost that should have been incurred. If the actual cost of work performed at a time is higher than BCWS, it is known that the contractor is currently overrunning cost and that the contractor's estimate at completion (EAC) may be higher than the Budget at Completion (BAC). Initial contract sum/estimated cost/tender sum/final bid of building project is the amount of money stipulated in the contract agreement between the client and contractor during tender negotiations. This means the sum of money in the tender (Buchan et al., 2003; Cantarelli et al., 2010; Flanagan and Tate, 1997; Hendrickson, 2008; Shr and Chen, 2006; Ugulu and Ikwuogu, 2011). The difference between the contract sum and final account provides a measure of construction cost performance and this could be positive or negative depending on how efficiently the contract was managed.

Similarly, estimated construction duration is the length of time that the client or client’s representatives (consultants) agree with the contractor as the work period, from the date of contractor’s possession of the site, to practical completion (Buchan et al., 2003, Shr and Chen, 2006, Ugulu and Ikwuogu, 2011). Construction project delay is an extension of construction duration beyond the estimated duration (Aibinu and Jagboro, 2002; Assaf and Al-Hejji, 2006; Davison and Mullen, 2009; Lo et al., 2006). Some scholars explain delay as the lagging behind schedule of one or two activities on the work programme or the slowing down of work without stopping entirely (Bartholomew, 1998; Bramble and Callahan, 1987). Other scholars refer to time overrun as the permanent difference between the estimated and actual construction durations (Chan, 2001; Choudhry and Phatak, 2004; Flyvbjerg et al., 2003a; Kaming et al., 1997; Oko et al., 2010 and Sinha et al., 2004). In that context, delay, or the temporary holdup of work can be tracked and corrected while work progresses, but time overrun is not redeemable because work at the site had closed. In the case of time overrun, the contract may have been completed though not on schedule. Delay and time overrun are sometimes used interchangeably, implying no difference between the two terms (Divya and Ramya, 2015; Memon et al., 2012b; Mohammad, 2010; Mubarak, 2005; Stumpf, 2000). Authors like Abbas (2006), Abdullah (2010), Chidambaram et al. (2012), Mukuka et al. (2013), Pourrostam et al. (2011), Sambasivan and Soon (2007), Sunjka and Jacob (2013), Vidalis and Najafi (2002) have been consistent in the use of the term project delay. Delay is classified into four, critical or non-critical, excusable or non-excusable, concurrent or non-concurrent and compensable or non-compensable (Abdullah, 2010; Vidalis and Najafi, 2002).

Delay leads to time overrun (Lo et al., 2006). Construction duration although, is most important to the investment client (Ameyaw et al., 2012 and Mak, 2000,), cost deviation has greater implication to all and sundry (Ali and Kamaruzzaman, 2010, Arcila, 2012; Memon et al., 2010; Memon et al., 2012b, Rahman, et al., 2013b). Actual construction duration is the actual duration of works from date of contractor’s possession of site to date of practical completion; which may not tally with the initial construction duration agreed between the contractor, clients and consultants (Gambo et al., 2012; Ugulu and Ikwuogu, 2011). The difference between the estimated construction duration and actual construction duration provides a measure of construction time performance, and this could be positive or negative, depending on how efficiently the contract is managed.

Managing the variables encountered during construction to nip in the bud the deviations between the targeted and actual project outcomes, is a major undertaking of the contractual parties (Davey, 2000). The inability of contractual parties to manage a construction project to match the tender sum and estimated construction duration with the final cost and actual duration, eradicates the two major success criteria of the project. Since changes in the initial and final outcomes of construction projects are not limited to one contractor, or to a single economy (Aljohani et al., 2017; Wa'el et al., 2007) it suggests the existence of a relationship between the initial contract sum vsfinal cost, estimated construction duration vsactual construction duration, and other factors responsible for the differentials, possibly at project execution stage. Such intervening factors include increases in the price of resources, variations (work change orders) (Mbamali and Nnorom, 2002), day works, inadequacies of provisional and prime cost (PC) sums, work delays (Kanoglu and Sezgin, 2004; Odeyinka et al., 2012) and fraudulent practices.

Abdelgawad and Fayek (2010), Ameh and Osegbo (2011), Azis et al. (2013), Kikwasi (2012, Olawale and Sun (2010) listed the project itself as one of the causes of construction cost and time overruns. Project peculiarities include unforeseen site and soil conditions, undefined and unclear project scope, location and environmental restrictions, size of work and project complexity.

Many researchers as Bosch-Rekveldt et al. (2011), Chen et al. (2004) and Molenaar et al. (1998) have supported Baccarini's (1996) view that project success is dependent on the complexity of a project, having a direct effect on the overall project performance. Complexity is a key characteristic of construction projects. It is the degree of complexity that determines the overall approach to a project specifically the required resources as well as tools and technques (Brockmann and Kahkonen, n.d). Complexity is also one of the critical project characteristics that determine appropriate actions to result in successful project outcomes (Baccarini, 1996). According to Azim et al. (2010), Wood and Gidado (2008), Xia and Chan (2012) there seems to be no universally accepted definition of the term "project complexity".

In addition, no model has been proposed for the quantification of construction project complexity (Brockmann and Kahkonen, n.d). It is on this basis that Gidado (1996) interviewed a few experts and presented the results, saying that professionals see a complex construction project as that with the following characteristics: The project has many different systems that need to be put together and with many interfaces between elements; The project involves construction work on a confined site with difficulty of access, and requiring many trades to work near and at the same time; One with a great deal of intricacy, for which it is difficult to specify clearly how long it would take; One which requires a lot of details about how it should be executed; One which requires efficient coordinating, control and monitoring from start to finish; One which requires a logical link, because a complex project usually encounters a series of revisions during construction and without interrelationships between activities it becomes very difficult to successfully update the programme in the most efficient manner.

According to Ade-Ojo and Babalola (2013) because prospective contractors are only interested in the financial gain for their construction contract businesses, their bidding principle is to become the lowest bidder always. As a result, they tend to win the contract first and get the opportunity to make claims as work proceeds and this leads to cost overruns. With such a scenario, the authors stressed, achieving reasonable performance in terms of cost and time cannot be guaranteed. Such latent contractual rules of operation held by contractors are not good for the health of the construction industry.

With global variations of the causation factor, construction projects consistently recorded cost and time overruns (Agren et al., 2011; Ali and Kamaruzzaman, 2010; Azhar et al., 2008; Cantarelli et al., 2010; Davey, 2000; Flyvbjerg et al., 2009; Hasan et al., 2014; Kasimu, 2012; Magnussen and Olsson, 2005; Memon, et al; 2012a and 2012b; Odediran and Windapo, 2014; Otunola, 2008; Rahman et al., 2013b; Rowland, 1981; Winch, 2010). Cost and time overruns are a serious problem in developed and developing countries (Acharya et al., 2006; Angelo and Reina, 2002; Chimwaso, 2001; Cooke-Davies, 2002; Lee, 2008; Odediran and Windapo, 2014). Overruns negate the projected budgets and account for numerous abandoned projects (Amusan, et al., 2013a; Lock, 2007, Otunola, 2008) in situations where funds earmarked for contingencies were insufficient. According to Angelo and Reina (2002), cost overrun is a serious problem that needs to be understood, treated and alleviated. Prominent past projects with cost overrun include the Suez Canal, which cost 20 times the earliest estimates, the Sydney Opera house 15 times more than originally projected, and the Channel tunnel between the United Kingdom (UK) and France, which had a construction cost overrun of 80%. Other examples of projects with problems of variability between the set targets and the achieved targets, are Shell’s Sakhalin II project with a planned cost of $10 billion in 2003 and a final cost of over $22 billion which was completed two years later (Flyvbjerg et al., 2005). Similarly, many projects in the Canadian Oil Sands experienced a 50% to 100% cost overrun, as did other numerous offshore developments, refineries, and pipeline projects (Edwards and Kaeding, 2015). Hackney (1992) found that nine out of every ten construction projects generally had cost overruns of 50 to 100%. The trend according to the author persisted in a seventy-year period, for which records were available for research purposes.

Nnorom (1998) discovered that, in the Nigerian construction industry, almost all projects are being completed at sums much higher than specified by the initial contract. For example, the Amenity Hospital Kaduna, Specialist Hospital in Minna, Presidential Lodge Abuja, and the Nigeria Institute of Transport and Technology (NITT), Zaria, increased by 63%, 138%, 75% and 128% respectively over the initial tender sums. In addition, Giwa’s study (1988a) of 90 completed projects found a cost overrun of 36.02%. Kasimu (2012) grouped causes of cost overrun in Nigeria into five major headings. These are financial factors, construction parties-related factors, construction-related factors, environmental factors and policy and fiscal measures-related factors. In addition, Mbachu and Cross (2015) cited external parties such as local councils and utility companies' influence among factors of cost overruns.

More of the causes of delay and time overrun on projects include: estimated construction programmes being either too long or too short from onset (Aiyetan, et al., 2012; Jarkas, 2016), clients making changes to the original design (Bowen et al., 2002), owner's lateness in submitting drawings and specifications, and in decision making (Ogunsemi and Jagboro, 2006), inadequate managerial skills, lack of planning and poor understanding of accounting and financial principles, poor performance, and the main contractor's poor coordination of specialist and sub-contractors (Nguyen et al., 2004). Designer-based delays include: faulty design, lateness in submitting drawings and specification, changed orders (Jarkas 2016; Oseghale and Olugbenga, 2008). Delays are results of unforeseen ground conditions, inadequate project scope, inclement weather and disputes among parties to the contract (Ahmad et al., 2002; Assaf and Al-Hejji, 2006; Odeyinka, 2000 and Odeyinka et al., 2012). Overruns in construction projects produce immediate negative effects on stakeholders and national economies (Edwards and Kaeding, 2015; Smith, 2006).

Many previous studies on construction project performance, for example Aiyetan, et al. (2011), Ali and Kamaruzzaman (2010), Baloyi and Bekker (2011), Bamisile (2004), Bromilow (1969), Dakas et al. (2004), Edwards (2015), Idoro (2012), Olawale and Sun (2010), Oshodi and Iyagba (2013), Odediran and Windapo (2014), Mbachu and Cross (2015) either combined or separated the two challenges. However, they seem to be inadequate in terms of either methods used or results obtained, or both. Bromilow's 1969 model related construction duration with cost in a mathematical formula, which other studies reviewed for adoption, and in some contexts modified for location suitability. Dakas et al. (2004) attempted to relate cost overrun with time overrun, but the result showed no relationship, though the study population (ten residential and ten commercial buildings) needed larger samples to enhance result validity. Olawale and Sun (2010) focused on investigating the inhibiting factors to research efforts on the treatments of overrun occurrences together with the mitigating measures; however, the measures proffered were not modelled. Baloyi and Bekker (2011) in a single study combined time and cost overruns, but not beyond finding the causes of each overrun. Mbachu and Cross (2015) explored ways of eliminating or narrowing the variance between initial and final construction costs through risk minimization and improved reliability on price forecast in the construction industry. However, the study is silent on the modality for computing the recommended contingencies to be allowed in the tenders. The authors argued that the sum stipulated as a contingency varies from contract to contract, and amounts used were subjective. Ali and Kamaruzzaman (2010), Bamisile (2004), Edwards (2015), Idoro (2012) and Oshodi and Iyagba (2013) offered managerial strategies for solving problems of time and cost overruns. However, none of the research focused on developing predictive models to solve the problems, and that is the concern of this present study.

Jarkas (2016), Ogunsemi and Jagboro (2006) assessed available research results, especially those on duration prediction, and concluded that predicting project duration with reasonable accuracy is a problem of continuous concern and interest to both researchers and industry practitioners. Recent attempts by researchers to solve the problems of cost and time overruns have led to the use of information and communication technology, aimed at improving methods used to date. Notable studies on construction cost and time forecast modelling includes Achuenu and Kolawole (1998), Achuenu (1999), Aiyetan et al. (2012), Amusan et al. (2013a), Amusan et al. (2013b), Gandu (2014), Giwa (1988b), Gonzalex (2007), Gunaydin and Dogan (2004), Larkin et al. (2012) and Odeyinka et al. (2012). Giwa (1988b) appraised and predicted the final contract sum of building projects with a multiple linear regression (MLR) model. Achuenu and Kolawole (1998) assessed and modelled cost overrun of public buildings in Nigeria with a multiple linear regression (MLR) technique. Furthermore, scholars such as Aiyetan et al. (2012) explored the relationship between the estimated and final construction times and developed an MLR model for a reasonable estimation of the final construction duration; however, the models focused on project durations. The foregoing are examples of studies on each of the challenges, using an MLR technique. Gonzalex (2007) did a preliminary investigation into the possibility of using fuzzy mathematical models for construction project scheduling. The result confirmed the practical relevance of the technique to the construction industry, although it failed to develop impact-predicting models for final construction cost and time.

Larkin et al. (2012) investigated the impact of risk factors on the variability between the project planned cost and the outcome on client-led and contractor-led design and build projects, with a view to developing prediction models for the construction contractor’s use, to evaluate the impact of risks occurring at project level on the final account. However, Larkin et al. (2012) failed to provide a model for final cost prediction. Amusan et al. (2013a), Gunaydin and Dogan (2004) developed models for early cost estimation for only the structural elements of buildings, to assist the engineer in making alternative choices of materials (with cost differences) at the design stage. The model designed by Gandu (2014) seems not to have captured all the cost-influencing variables used in the design of the forecast model. Among such factors are the contractor's managerial powers and gratuities to the staff of the project quality/quantity monitoring and approving agencies. Moreover, Gandu (2014) recommended a process flow chart for improvement directed at building production cost management, not cost or time predictions. Odeyinka et al. (2012) modelled risk impacts on the variability between contract sum and final account only and used a limited dataset of 19 projects, and the UK as the study area. The models for construction cost and time impact predictions proposed in this research as emphasized in Wang et al., (2012) are part of the new information and communiction dimensions for tackling cost and time variability challenges in the construction industry.

Though decision milestones may be used to anticipate outcome, risk management used to prevent variability, and sequential iteration used to ensure the desired targets are achieved, projects still end up with scheduled delays and budget overruns (Balogun, 2005; Meyer et al., 2002; Nguyen et al., 2004 and Stumpf, 2000). This is because most construction projects are complex and intrinsically full of uncertainties, with the dynamics creating difficulties for project managers. Notwithstanding the attempts to provide solutions to the problem of project cost/time initial-and final-figure variability, still the challenges remain a global phenomenon (Yakubu and Ming, 2009). Efforts aimed at making final construction cost and time equate with their initial estimation, have largely been reactive, instead of proactive (Clen and Smith, 2001; Kaliba et al., 2009; Sambasivan and Soon, 2007). The results practically have been the failure to respond adequately to the challenges, with poor levels of success in construction project delivery (Jarkas, 2016; Lock, 2007; Nguyen et al., 2004; Vidalis and Najafi, 2002). Despite efforts made by stakeholders to improve the situation both theoretically and practically, construction facilities still deliver late and above budget (Aibinu and Jagboro, 2002; Ahiaga-Dagbui et al. 2015; Ameh and Osegbo (2011); Aiyetan et al., 2012; Flyvbjerg et al., 2003b; Jarkas, 2016; Love et al., 2015; Nguyen et al., 2004; Willoughby, 2005). Some of the reasons behind the non-improvement include limited sample sizes and the inadequacy of parametric formulated models (Love, et al., 2005). Moreover, there is a dearth of artificial intelligence methods for prediction and assessment of construction project cost and time performance. Of some studies on construction project cost and time performance shown in Appendix XXIX, which used an artificial neural network system, only 7.14 % of them are based on African locations, and all of them focus on Nigeria only.

To fill this gap in knowledge, this study examines the impact of construction cost and time-influencing factors on the production performance of public building projects in north eastern Nigeria with a view to enhancing project delivery. This is aligned with Odeyinka et al. (2012), Smith and Mason (1997) and Wang et al. (2012), but in a different context. Noted among past studies that encouraged further investigations with the ANN approach, is the one by Gunaydin and Dogan (2004). The authors noted that the technique might solve the complex non-linearly related variable mappings, for the prediction of the total building cost at any phase in the design and construction processes. The same holds for construction programme monitoring, for progress tracking and updating. Survey data sourced for designing the models were: the initial contract sum, the estimated construction duration, final cost, actual construction duration and the influence of the intervening cost and time drivers at the execution phase of the projects.

1.3 Statement of the research problem

Variability between initial contract sum, final cost, and estimated and actual construction duration is a global phenomenon. The consequences go beyond delays in project completion to project abandonment and failures in situations where enough extra funds were neither set aside nor available to mitigate the overruns. Generally, in the construction management field, there is a dearth of studies into using machine learning systems such as artificial neural networks for advanced cost and time impact predictions and performance assessments (Flyvbjerg et al., 2003a). Considering all the research studies on construction project cost and time performance that used the artificial neural network system, only 7 % are based on African areas. Such prediction and performance measurement tools for construction project cost and time can possibly be developed from the examination of data on initial contract sums, estimated construction duration, final cost, actual construction duration, influence of cost and time driving factors on public building projects in the study area. In using the proposed models to assess cost and time impacts (overruns) for a project under construction, the user first extracts the values associated with the significant driving factors as inputs. The values are keyed into the models and the network output recorded. The model automatically predicts the difference on either the initial cost or schedule of the project, for management decisions.

1.4 Research questions

Guided by Akogun (2000), the following main research question was investigated by this study: What predictive model could be devised for assessing the impact of construction cost-and-time-influencing factors on public building project production performance in north eastern Nigeria?

To address the main question, the following sub-questions were examined:

i. What are the factors influencing the cost and time performance of public building projects in north eastern Nigeria?
ii. What is the cost-and-time performance of selected public building projects in the study area?
iii. How do the cost-and-time performances of uncomplicated, moderately complex and largely complex projects compare?
iv. What are the impacts of project complexity on construction cost-and-time performance?
v. What is the relationship between influence and the impacts of construction cost-and-time driving factors?

1.5 Research aim

Examine the impact of construction cost-and-time-influencing factors on the production performance of public building projects in north eastern Nigeria and whether a predictive model could be devised in assessing this impact.

1.6 Research objectives

The research objectives are to;

i. Assess the factors influencing the cost-and-time performance of public building projects in north eastern Nigeria.
ii. Determine the cost-and-time performance of selected public building projects in the study area.
iii. Conduct a comparative assessment of cost-and-time performance of selected uncomplicated, moderately complex, and largely complex public building projects in the study area.
iv. Examine the impact of project complexity on cost-and-time performance of selected public building projects in the study area.
v. Develop models for assessing the impacts of cost-and-time influencing factors on cost-and-time performance of public building projects in the study area.

vi. Validate the developed cost-and-time performance impact assessment models of public building projects in the study area.

1.7 Research propositions

P_1 Complex construction projects manifest higher overruns than less complex projects.

P_2 Significant relationships exist between cost-and-time influencing factors and cost-and-time performance of public building projects in the study area.

P_3 Relationship between cost-and-time influencing factors and cost-and-time performance can be used to develop a model for assessing the impact of cost-and-time influencing factors on cost-and-time performance, within a certain confidence limit.

1.8 Significance and importance of the research

Construction project planners at various levels need information and tools for use in the management of construction project cost and time. Since actual cost and duration of projects do vary from initial targets, the results are delays in situations where sudden and sufficient additional resources are not immediately available to complete the project. Sometimes the projects may perpetually remain uncompleted where the required extra funds could not be sourced (Adewuyi and Anigbogu, 2006). At the construction stage, cost and time influencing factors interact, contractors and consultants usually lack ideas on how much such interaction impacts on project cost and duration, until the end of construction. Mechanisms for forecasting the magnitude of the inevitable extra funds and additional time, while the project is ongoing, are extremely important. Such predictive tools required for effective and efficient control of cost of construction projects are not currently popular among construction resource estimators, particularly in the Nigerian building industry. The artificial neural network for construction project cost and duration prediction is now one of such tools. The design of prediction network models and their use is expected to benefit the industry, while the designs contribute to the existing body of knowledge.

Firstly, the research results may be additions to existing studies aimed at extending the knowledge and advantages of the Artificial Neural Network system over other statistical and programmed analytical tools in the field of building production economics and management generally to the Nigeria construction industry, and particularly to the northeeastern zone. Olatunji (2008a) made a clarion call to professional institutions in the Nigerian construction industry to use all available mechanisms to rise to the challenges of professionalism in the industry after the discovery of variants in project duration as wide as -33 to 1,250%. The proposed models may be beneficial to (i) clients and consultants, by the provision of guidelines for the determination of extra funds and time required during project completion, (ii) to the contractor who is sometimes penalized for late delivery, and in extreme cases is blacklisted from further construction business with clients, (iii) the completion of building promects within schedule and budgets, (iv) public construction project monitoring agencies like the Nigeria Bureau of Public Procurement (BPP), which may be assisted by the developed cost-and -time impact assessment models in providing their services.

Secondly, the update on the significant construction contract cost-and-time drivers in the study area may improve construction managers' knowledge, because awareness and considerations of such driving factors may reduce the current level of poor performance in the project management field, towards successful projects in the future.

Thirdly, architects and construction managers in Nigeria as well as construction project cost accountantants may use the study results to improve on the existing knowledge of variability between the initial and final cost-and-time objectives, caused by levels of construction project complexity.

1.9 Scope (limitations) of the research

Since building property cost and duration of construction are influenced by pre-contract, construction and post-contract factors, boundaries of the extent of this study were set on the project construction phase. Construction stage is the period when the physical form of the project is created from the designs and specifications. This study addressed challenges within the construction execution stage, where client, consultants and contractors take responsibilities for the management of issues related to project cost growth and programme extensions. Sweis et al. (2013) posited that there is no element in any project that is solely responsible for overruns, however; the construction phase holds a wider proportion of major challenges. Therefore, the construction phase is considered a critical phase where most drivers of planned cost and duration interplay (Chan and Kumaraswamy, 1996 and1997, Frimpong et al., 2003; Roslan et al., 2015) causing disruptions to planned project objectives. Property market, land acquisitions and legal challenges relating to cost and time of delivery are not within the scope of this research.

Fourty-three (43) and Fourty-nine (49) construction project cost and time factors identified from the literature were therefore investigated in the study area. Data sourced for analysis relates to 246 completed public building projects in the study area, constructed between 2012 and 2017 by registered corporate construction firms, and their processes managed by consultants and clients in-house built environment professionals. Using Altshuler and Luberoff's (2003) classification, ten of the projects are largely complex projects, 30 moderately complex projects and the remaining 206 are uncomplicated (See Appendix XXXIII).

1.10 Overview of the research methodology

Most theories in the construction management field are based on an ontology (knowledge existence), which assumes an orderly and objective view of reality that can be known and uncovered through research (Knight and Ruddock, 2008; Richard, 2010). The philosophy (a set of beliefs that guides the conduct of this research) is based on an objective reality. And in terms of nature of knowledge, justification and rationality of beliefs (epistemology) this research is based on objective knowledge that exists independently of the researcher (Knight and Ruddock, 2008; Richard, 2010; Pham, 2018). Epistemologically, this research is therefore, premised on the positivist paradigm and is objectivist in that the reality of the findings is deduced through cost and time values obtained from building projects records and observations. Positivism is based on the natural model of dealing with facts (Noor, 2008) and takes an objective dimension (Perry, 1998). Objectivity of the reality is also not rejected even when the constructivist philosophy is used which talks about the subjective human creation of meaning (Baxter and Jack, 2008). The positivist paradigm on which this research is based assumes that the nature of knowledge is independent of the knower and his or her perspective (Knight and Ruddock, 2008), the social world is objective, and in this research, the researcher is trying to understand what is happening.

The study adopts a quantitative approach to research design and data collection (Abowitz and Toole, 2010), the exploratory research approach involves the collection of quantitative data (Ivankova et al., 2006). The design of this research allowed quantitative data to be collected and analyzed to prove empirically the relationship between the cost impact and the influence of the cost driving factors to generate a cost impact forecasting model. Similarly, the design allows for data to be collected to prove empirically the relationship between the time impacts of construction projects and the influence of time driving factors to generate a model to forecast the impact of duration. More details on the methodology and methods are provided in Chapter Four of this study.

1.11 Definition of terms

1.11.1 Initial contract sum

The "initial contract sum", "estimated cost", "tender sum" and "final bid" though not equivalents are terms used interchangeably to refer to the amount of money stipulated in the contract agreement as the cost of the proposed construction project, that is, the sum of money in the tender (Buchan et al., 2003; Cantarelli et al., 2010; Flanagan and Tate, 1997; Hendrickson, 2008; Merrow et al., 1988; Shr and Chen, 2006; Ugulu and Ikwuogu, 2011). The term "initial contract sum" is consistently used later in the study to mean the same as tender sum, final bid or planned project cost.

1.11.2 Estimated construction duration

"Estimated construction duration" or "planned project duration" is the length of time that the client or client's representatives (consultants) agree with the contractor as the period for which work will last on site, from the date of taking possession of the site, to the practical completion of the project (Buchan et al., 2003; Shr and Chen, 2006; Ugulu and Ikwuogu, 2011). The term "estimated construction duration" is used in the rest of the report to mean the planned or scheduled period of construction.

1.11.3 Final account

"Final account", "actual construction cost", "as-built cost" and "final contract sum" refer to the actual amount of money due to the contractor (Martin et al, 2006) certified by the prime consultant and agreed by the client as the value of work completed by the contractor. This may or may not be the same figure as the initial contract sum (Butler, 1988; Cantarelli et al., 2010; Gambo et al., 2012; Hammad et al., 2008; Hendrickson, 2008; Ugulu and Ikwuogu et al., 2011). "The final account" has consistently been used in the rest of the study to mean the same as "as-built cost", "actual construction cost" or "final contract sum".

1.11.4 Actual construction duration

"Actual construction duration" is the elapsed period the contractor takes to completely execute work at the site, from the date of taking possession to the date of project commissioning (Guerrero et al., 2014; Martin et al, 2006). It may or may not tally with the estimated construction duration agreed among the contractor, client and consultants (Gambo et al., 2012; Ugulu and Ikwuogu, 2011).

1.12 Structure of the thesis

The thesis comprises seven chapters. Chapter one outlines the general introduction of the thesis; background to the study, problem statement, research questions, aim and objectives, propositions, and significance of the study. Other sections in the chapter are the scope of the study, an overview of the adopted research methodology and the structure of the thesis.

Chapter two presents definitions and explanations of terms that formed the background to the understanding of the thesis. The poor cost-and-time performances of public building projects are discussed with the causation factors and their influences on construction contract cost-and-time objectives. The inappropriateness of multiple linear regressions technique in prediction modelling with non-linear multiple input variables is highlighted in this chapter. The introduction of the artificial neural network (ANN) forecast model into construction is reviewed, together with a comparison of the prediction accuracies of multiple linear regression (MLR) equivalents.

Chapter three which is the conceptual framework, recaps on the contemporary industrial status of construction projects cost'-and-time performances presented in Capter Two. The chapter further discusses the intertwined nature of some cost-and-time influencing factors on the final cost and actual duration of construction projects, as well as cost overrun theory. The discussions give background to the identification of the current gap in knowledge that culminates in the study's conceptual framework.

Chapter four discusses the research philosophy, research methodology and methods comprising the approach adopted for data collection, as well as the data collection procedures. In addition, the chapter discusses the study area, questionnaire design, and sample size determination criteria, sampling techniques, the pilot survey, questionnaire administration and response. Methods used in the analysis of data are discussed. The adoptability of ANN into construction management and modalities for adoptions into construction project cost and time impact predictions and assessments is briefly discussed. The chapter ends with discussions on ethics observed in the research conduct.

Chapter five presents the research data analysis and results which are discussed in line with the research aim and objectives. These are the topmost five construction cost and time driving factors generally (total group) and the significant factors from the perspective of each stakeholder. The factors aree reduced into major components with the technique of Principal Component Analysis. Cost-and-time performance across the study area are determined. Cost-and-time performances in uncomplicated, moderately complex and largely complex construction projects are compared, and investigations of project complexity impacts on construction project time performance are described. Using the 80/20% Pareto rule, the significant factors are determined in both cost and time constructs. The influence of the significant factors, together with their cost and time budget deviations were used in the development of predictions and performance assessment models. The research objectives, excepting validation of the developed models, are noted as achieved in this chapter.

Chapter six presents the impact model validations: the construction project cost-and-time impact prediction models developed with multiple linear regression (MLR) and artificial neural network (ANN). The models are compared for impact prediction accuracies in terms of mean absolute percentage errors (MAPE), mean square errors (MSE), and relative mean absolute deviation (Rel.MAD).

Chapter seven presents a summary of findings from the literature and empirical research, contributions to knowledge, practical implications of the research results, conclusions and recommendations, study limitations, and recommendations for further studies on the research problem.

1.13 Summary of general introduction

Construction project success indicators of cost, time and quality were discussed as well as the prevalence of costruction cost and time overruns with a brief of the causation factors. Previous studies on construction project cost-and-time performance were highlighted, with the gap yet to be addressed in terms of ANN network models for predicting construction project cost and time. The research statement of the problem therefore evolved from the foregoing, upon which the research questions, aim, objectives and propositions are based. Also, the significance of the study, and the scope of the study, with an overview of the adopted methodology, were discussed. The chapter further defined and explained the terms used repeatedly in the study; independent and dependent variables comprising initial contract sum and final account, estimated and actual construction duration, cost and time influencing factors. The terms gave a background for the discussion of public building project performance and the effects of cost and time overruns discussed in the next chapter, the literature review. The chapter closed with a discussion of the thesis structure.

CHAPTER TWO: CONSTRUCTION COST AND TIME PERFORMANCE: EFFICACIES OF MLR AND ANN TECHNIQUES

2.1 Introduction

The Chapter reviews extant literature with the discussions of government spending on public buildings, project overruns and effects, factors of overruns and the assessments of the impact and influence of construction cost and time factors. Modelling of the relationship between variables as influences and impacts of overrun factors is discussed together with the orthodox mathematical regression modelling technique. The inappropriateness of the multiple regression modelling technique for construction cost and time objectives determination is discussed. The method for determining contingent funds and extra time above the basic cost and schedule, is highlighted. The discussion forms the background for the introduction of artificial neural network models into construction cost-and-time performance assessments. The Chapter thereafter highlights the advantage of the precision of the ANN technique over the MLR technique, which could aid research concept formulation.

2.2 Public buildings construction and maintenance budgets

The earliest use of the term "public building" was made by Thomas Hoby (1530 – 1536). It meant a building used by the public for any purpose, such as assembly, education, entertainment or worship as well as residential (Olatubara and Fatoye, 2006). This implies that a public building is one constructed by and belonging to a town, local, state or federal government for official use or for investment purposes. Examples of public buildings are government-owned residential and industrial estates; roads, water projects, dams and power stations are public building projects (Oraegbune, 2008). Also included in public building projects are office complexes, educational and health institution buildings (Onifade, 2003), military and paramilitary barracks, and parliamentary complexes. These constitute a large percentage of annual government investment. In summary, public buildings are any buildings or portions thereof other than a privately owned residential structure, police, fire, or correctional facility, constructed wholly or partially with state or municipal funds, whether tax funds, funds obtained through bond issues or grants or loans under any state law, which is likely to be used by physically handicapped persons including but not limited to theatres, concert halls, auditoriums, museums, schools, libraries, recreation facilities, transportation terminals and stations, factories, office buildings and business establishments.

Governments spend much of their scarce financial resources annually on construction and maintenance of building and infrastructures. A breakdown of allocation to federal government owned universities, polytechnics and colleges of education is shown in Table 2.1. In years, 2007 and 2008 over ₦125bn naira (342.47million USD) and ₦149bn naira (408.22million USD) were allocated to federal universities, polytechnics and colleges of education. It can also be seen from the table that federal government earmarked the sum of ₦47.76 bn naira (130.85million USD) for capital project development in higher educational institutions between 2006 and 2008.

Table 2.1: Federal government of Nigeria's allocations to higher educational institutions (2006-2008)

Institution Type	Year	Personnel	Goods and Non-Personnel	Capital	Total
Universities	2006	69,952,108,028	3,175,567,183	6,412,015,000	79,539,690,211
	2007	70,600,358,870	5,584,703,445	8,285,015,000	84,470,077,315
	2008	86,078,825,055	3,551,429,669	13,958,579,185	103,588,833,909
Polytechnics	2006	18,990,972,823	1,715,916,763	2,164,746,264	22,871,635,850
	2007	19,443,992,823	1,895,916,763	2,424,746,264	23,764,635,850
	2008	22,024,993,058	2,149,712,599	3,578,057,860	27,752,763,517
Colleges of Education	2006	10,911,206,151	1,067,435,864	3,063,175,000	15,041,817,015
	2007	11,401,898,534	1,207,987,217	4,991,020,000	17,600,907,751
	2008	14,088,802,102	1,279,807,659	2,882,329,309	18,251,939,070
Total	2006	99,854,287,002	5,959,919,810	11,639,936,264	117,453,143,076
	2007	101,446,230,227	8,688,609.425	15,700,781,264	125,835,620,916
	2008	122,192,620,265	6,980,949,927	20,419,996,345	149,593,536,496

Source: Bamiro (2012: 15)

The sum of one hundred billion naira was released in 2013 by the Federal Government for the construction and renovation of infrastructures in the States and Federal Universities (Oyedele, 2013). Efficient management of construction projects aimed at controlling variability between planned and actual targets of cost and time is therefore important in justifying the huge sums expended annually on public buildings and infrastructure.

2.3 Construction project cost and time performance

Cost-and- time overruns (variability) are the excess amounts of money and time over and above the initial contract sum or estimated duration (Avots, 1983; Azhar et al., 2008; Bramble and Callahan, 1987; Chan, 2001; Choudhury and Phatak, 2004; Dlakwa and Culpin, 1990; Elinwa and Joshua, 2001; Kaming et al., 1997; Lo et al., 2006; Pickavance, 2005; Shrestha et al., 2013; Trigunarsyah, 2004).

Performance is the degree of achievement of a planned target (Chitkara, 2009; Ganiyu and Zubairu, 2010). As stated earlier, major success parameters of construction projects common to all stakeholders are, cost, time and quality (Ahsan and Gunawan, 2010; Ali and Kamaruzzaman, 2010; Apolot et al., 2015; Atkinson, 1999; Bamisile, 2004; Bhangale, 2016; Borse and Khare, 2016; Chan and Kumaraswamy, 2002; Chan & Chan, 2004; Chan et al., 2004; Dursun and Stoy, 2011; Mak, 2000; Oyedele, 2012; Rwelamila and Hall, 1995; Shr and Chen, 2006; Shreenaath et al., 2015 and Stojeetovic et al., 2014). A successful project is, therefore, one that maintained its schedule, remained within the budgeted costs and accomplished other objectives (Memon et al., 2012b).

Globally and particularly in developing countries, construction projects are delivered late and over budgets (Achuenu and Kolawole, 1998; Adam et al. 2014; Ahiaga-Dagbui and Smith, 2014; Aibinu and Jagboro, 2002; Akewusola, 2007; Azhar et al., 2008; Balogun, 2005; Baloyi and Bekker, 2011; Flyvbjerg et al., 2014; Gidson, 2012; Giwa, 1988a; Memon et al., 2010; Meyer et al., 2002; Nguyen et al., 2004; Roslan et al., 2015; Rwelamila and Ogunlana, 2015; Stumpf, 2000; Willoughby, 2005; Yakubu and Ming, 2009). Poor performance was recorded on World Bank projects, in which 63% of the 1778 constructions faced overrun in the budget at an average of 40% (Ameh et al., 2010 and Zujo et al., 2010). Flyvbjerg et al. (2004) concluded that 9 out of 10 infrastructure projects overrun their cost budgets by an average of 86%. Cost overruns are problems in developed and developing countries (Angelo, 2002, Azis et al., 2013), and the trend is more severe in developing countries (Azhar et al., 2008, Shanmugapriya and Subramanian, 2013, Sweis, 2013) where these overruns sometimes exceed 100% of the anticipated cost (Memon et al., 2010). A survey of 104 public projects in Singapore indicated that nearly two-thirds suffered from cost overruns and more than half delivered behind schedule (Ke et al., 2013). The Miller and Lessard (2000) International Program in the Management of Engineering and Construction (IMEC) revealed that 18% of 60 large engineering and construction projects of $1 billion USD average capital value undertaken between 1980 and 2000 incurred extensive cost overruns. The Edinburgh Trams project exceeded its initial budget leading to significant scope reduction to curtail the cost growth (Ahiaga-Dagbui and Smith, 2014). Olawale and Sun's (2010) survey in the United Kingdom found about 59% of respondents had experienced cost overrun more than 10% of the initial contract sum. In Bosnia and Herzegovina, Zujo et al. (2010) noted maximum contracted price overrun of 29.16% at an average of 6.84%. The study by Frimpong et al. (2003) in Ghana revealed that 75% of the projects exceeded the original project cost; only 25% were completed within the budget. In Malaysia too, the problem of cost overrun is a serious issue; Abdullah et al. (2009) asserted that 90% of the large Majlis Amanah Rakyat **(**MARA) construction project suffered delays, with the significant effect of time and cost overrun, since 1984.

Like cost overruns, schedule delays for construction projects are a common occurrence (Anastasopoulos et al., 2012; Doloi et al. 2012; Meng, 2012). About 25% of the United States of America's arbitration cases were related to construction project delay (Kassab et al., 2006). In Australia, Bromilow (1974) found that only one-eighth of building contracts were completed within the scheduled completion dates and the average time overrun exceeded 40%. Studies on construction projects in some developing countries indicated that by the time a project is completed, the actual cost exceeds the original contract price by about 30 % (Al-Momani, 1996). Shanmugapriya and Subramanian (2013) asserted that time and cost overruns have become the hallmark of construction projects in India. In South Africa, time delays on construction projects are more of the norm than the exception (Baloyi and Bekker, 2011). Building Cost Information Service (BCIS) research indicated an average of 40% time overrun (Lowsley and Linnett, 2006). Delay is endemic in Nigeria (Aibinu and Jagboro, 2002), the industry is characterized by projects that are completed much later than planned (Mbachu and Olaoye, 1999). Odusami and Olusanya (2000) confirmed that most projects executed in the Lagos metropolis experienced an average time overrun of 51%.

Akewusola (2007) found the mean cost overrun in Nigeria in three periods; between 1972 and 1978, it was 46.76% of the contract sum, 65.83% from 1979 to 1983 and 23.39% from 1984 to 2007. Considering the level of government's expenditure on buildings and infrastructure annually, cost overrun could pose a great project management challenge, with unimaginable consequences on the availability of hostels, lecture theatre and libraries for the smooth institutional operations. Poor performances on construction projects are global phenomena ranging from the United Kingdom, to the United States of America and to Nigeria. This can be seen in Table 2.2. Cost-and-time overruns were seen on Scottish Parliament buildings completed in the UK in the year 2004, on the London Olympics completed in 2010, and on the United States of America Defence Headquarter buildings. Overruns in time also are recorded on projects in the United Arab Emirates, Norway, India and South Africa. Overruns on cost and duration of up 400% and 327.27% were recorded in Nigerian construction projects.

Table 2.1: Poor cost and time performance of public construction projects across the globe

Author and Study	Project Performance
United Kingdom	
The United Kingdom (U.K) national audit report for the year 2001 (Kassab et al., 2006)	70% of public projects had time overruns
Gidson, (2012). International Olympic Games National Audit Office [IOGNAO] (2012). The 2012 London Olympics bid awarded at £2.4 billion in 2005 was completed at £8.9 billion in 2010	Time overrun 100% and cost overrun of 270.83%
Scottish parliament buildings completed in 2004 (Flyvbjerg, 2004)	The cost rose to 16 times the original estimate
Humber Bridge (Flyvbjerg et al., 2003b)	175% cost overrun
France	
Paris Nord TGV (Flyvbjerg et al., 2003b)	25% cost overrun
Denmark	
The Great Belt link	54% cost overrun
Norway	
Odeck and Skjeseth (1995) assessed Norwegian toll roads to reveal whether planning procedure shortcomings experienced by Norwegian road agencies had resulted in poorer than projected financial performance and underestimation of construction costs.	In a sample of 12 toll projects, they found cost overruns at about 5%, but the interval was large from -210 to 170%.
Projects in the United States of America	
Denver International Airport. (Government Accountability Office, 1995)	$2.1 billion to $4.8 billion (128.57%)
The construction of the Erie Canal between 1817 and 1825 (Engerman and Sokoloff, 2004)	46 percent over budget and the canal's later expansion went 142% over budget.
The construction of the Sydney Opera House in the 1960s (Flyvbjerg, 2005)	Final cost was 14 times the original estimate
The construction of the Panama Canal between 1902 to 1913 by the Corps of Engineers (Maurer & Yu, 2008)	Cost was 106 % over budget, building ending up costing $75 million to build, more than double the original estimate of $35 million.
The Pentagon building itself, constructed in Virginia in the 1940s (Mann, 2007)	The Pentagon rose from $265 million to $621 million (134.34%)
Littoral Combat Ship (United States of America Government Accountability Office [USAGAO], 2015)	$360 million to $667 million (85.28% cost overrun)
DHS headquarters (Painter, 2013)	Grew from $464 million to $824 million (77.59% cost overrun)
National Ignition Facility (Chang and Broad, 2014)	From $2.10 billion to $5.30 billion (152.38%)

Author and Study	Project Performance
Clinch River Reactor (United States of America Congregational Budget Office [USACBO], 1983)	$400 million to $4.00 billion (900.00% cost overrun)
San Francisco Bay California Senate Transportation and Housing Committee. (New York Times December 2 2014).	From $1.40 billion to $6.30 billion (350% cost overrun)
NYC WTC Rail Station (Dunlap, 2014).	From $2.00 billion to $4.00 billion
World Bank's construction projects (Roslan et al., 2015; Sambasivan and Soon, 2007; Sweis et al., 2008, and Kaliba et al., 2009).	50% to 80% time overrun
United Arab Emirates	
Al-Zarooni and Abdou (2000) conducted a survey to investigate variations in UAE public projects' estimates.	They found that the variations (positive or negative) between feasibility and contract cost ranged between -28.5% and +36%.
Palestine	
Mahamid and Bruland (2012) conducted a study to investigate the relationship between actual and estimated cost of road construction projects using data from Palestinian road construction projects awarded over a 5-year period	The study was based on a sample of 169 road projects. The findings reveal that 100% of projects suffer from cost movements in various directions, while 76% of projects had cost underestimation and 24% had cost overestimation. The discrepancy between estimated and actual cost averaged 14.56%, ranging from -39.3% to 98%.
Malaysia	
Hamzah et al. (2009) reported on research conducted in the year 2005 in Malaysia	17.3 percent of Malaysian public construction projects had an average of three months delay and abandonment. More than 90% of the large MARA project experienced a delay (Memon et al., 2010).
India	
Ministry of Programme Implementation projects completed between 1989-1990 (Chitkara, 2009)	17.3 percent of projects had an average of three months delay and abandonment.
South Africa	
The 2010 FIFA World Cup stadia in South Africa:	These projects had cost overruns of;
Soccer City – Johannesburg,	68.18%,
Ellis Park – Johannesburg,	5.41%,
Moses Mabhida – Durban,	93.75%,
Mombela – Nelspruit,	66.67%,
Green Point – Cape Town,	37.93%,
Nelson Mandela Bay – Port Elizabeth,	Not known,
Peter Mokaba – Polokwane,	Not known,
Royal Bafokeng – Rustenburg,	33.17%,
Mangaung – Bloemfontein,	46.50%,
Loftus Versfeld – Pretoria (Baloyi and Bekker, 2011)	7.38%
Uganda	
The Northern bypass in Kampala (Ssepuuya, 2008)	50% time overrun
Mapeera House on Kampala road. (Muhwezi et al. 2014)	77% time overrun
Nigeria	
Amenity Hospital Kaduna,	Increased by 63% over the initial tender sum
Specialist Hospital in Minna,	Increased by 138% over the initial tender sum
Presidential Lodge Abuja,	Increased by 75% over the initial tender sum

Author and Study	Project Performance
The Nigeria Institute of Transport and Technology (NITT), Zaria (Nnorom, 1998)	Increased by 128% over initial tender sum.
Upper Benue River Basin Development Authority Dam, Yola.	400% cost overrun, and 233.33% time overrun.
Structural Redesign and Modification of FUTY Library inherited from Federal Polytechnic, Mubi.	61.71% cost overrun, and 111.76% time overrun.
NIPOST area headquarters, Yola.	4515.38% cost overrun, and 683.33% time overrun yet uncompleted at the time of the investigation.
Federal High Court, Yola.	14.16% cost overrun, and 500% time overrun.
FUTY Faculty of Science	76.48% cost overrun, and 327.27% time overrun
FUTY Students' Hall of Residence; Police Command Headquarters, Yola; Faculty of Agriculture Complex, FUTY, Yola	9.40% cost overrun, and 50.00% time overrun; 144.63% cost overrun, and 160.00% time overrun
Yola-Mubi Toll Gate Plaza (Oraegbune, 2008)	49.37% cost overrun, and 83.33% time overrun 57.14% cost overrun and yet uncompleted as at the time of the investigation

The magnitude of overruns has not declined over time (Flyvbjerg et al., 2003b; Engerman and Sokoloff, 2004). It is evident from the foregoing that the construction industry has a challenging history of poor cost and time performance. Continuous efforts towards finding solutions to avert the consequences of systemic poor performance in the construction product development process are now demanded (Olatunji, 2008). Moreover, consistent cost and time overruns issue indicate the poor use of taxpayers' money (Apolot et al., 2015; Shrestha et al., 2013) as governments are the largest construction clients in most developing economies with major interest in public projects.

2.4 Effects of construction project overruns

Overruns have negative effects on clients, contractors, consultants, the construction industry, societies and national economies. In Nigeria, Oraegbune (2008) attributed effects of cost and time overruns on some state government projects. The State School of Nursing and Michika-Kuburhosho road project overran their cost and duration budgets, the results were late usage and the high cost of agricultural products in the case of the road project. Yola Modern Abattoir and Jimeta Shopping Complex recorded late usage, loss of revenue and dilapidations due to delay in delivery, also the time overrun in the completion of the Adamawa State Stadium Complex led to cost overrun. The author discovered an increase in contractor's overhead expenditure due to time overrun.

- Construction companies: many construction companies have failed (Charoenngam and Sriprasert, 2001) especially due to their inability to prevent cost overruns (Sriprasert, 2000).
- Construction industry: according to Flyvbjerg et al. (2007), cost overruns are considered problematic for the following four reasons; first, they lead to waste of resources. This is because additional budgets are required as projects become more expensive than was initially estimated, the budget for other projects are therefore affected, particularly as the total budget for buildings and infrastructure investments is often fixed in each period. In the public sector, money spent on revised project costs

and extended construction durations reduce the number and size of the projects that can be delivered in each fiscal year. Cost overruns thus result in both financial wastage and fewer projects realized than planned.

- National economies: Cost and time and overruns have significant economic and political implications (Shanmugapriya and Subramanian, 2013). The challenges reduce the productivity of available economic resources, limit development potential and diminish the effectiveness of the national economy (Haseeb et al., 2011). In India, Gupta et al. (2009) implied from government data that almost 60 percent of projects are overwhelmed by cost and time overruns, and if the trends continued, the country's eleventh and twelfth plan periods (2008 to 2017) could suffer a GDP loss of US$ 200 billion, estimated to be about 10 percent of its year 2017 GDP. Secondly, cost overruns lead to delays and further cost overruns. When confronted with cost overruns, attempts are made to secure additional funding and projects are often renegotiated and reapproved. This inevitably takes time, cost overruns increase with each additional year before implementation (Flyvbjerg et al., 2004). Thirdly, cost overruns destabilize policy, planning, implementation, and operation of projects. Cost overruns can lead to continuous reapproval and disorganisation in the project and parliament. Fourthly, when projects become more and more expensive and still involve cost overruns, the financial consequences can be so large that it even may destabilize the finances of a country or region.
- Clients and contractors: Cost overrun translates to profit losses to clients and contractors (Mbachu and Nkado, 2004; Nega, 2008; Zainudeen et al. 2008) and end-user dissatisfaction. The poor time performance of a construction contract has a direct effect on the profitability of the project from the perspective of all stakeholders (Akintoye and Skitmore, 1991, Abd-Majid and McCaffer, 1998). It implies profit loss by project owners, stemming from being unable to make use of the project at the agreed date, whilst to the contractor; extra cost incurred on labour and plant, payment of penalties or even loss of other profitable contracts, since resources for the next job are tied up on delayed projects (Ameh and Osegbo, 2011, Nuhu, 2013; Shen, 1997). Like cost, time overrun results in the growth of adversarial relationships, litigation, arbitration (Apolot et al., 2015). In a period of 74 years, 25% of the 1.7 million cases of American Arbitration Association were delay related (Kassab et al., 2006). Cost overruns have often led to extensive claims, disputes and lawsuits (Ahmed et al. 2003; Love et al., 2010; Mbachu and Nkado, 2004; Nega, 2008).

2.5 Construction project cost and time driving factors

According to Ahiaga-Dagbui and Smith (2012) a complex web of cost and duration influencing factors needs to be considered in the estimation of construction project cost and time. These include changes in design and scope, unforeseen site and soil conditions, programme delay; type of client, tendering method, inclement weather, poor site management, and delay in progress payments. Odeyinka et al. (2012) attributed project cost variability to the influence of such driving factors.

Poor performance on a construction project is a problem that translates to cost and time overruns (Ade et al., 2013). Numerous studies relating to causes of cost and time overruns have been conducted worldwide (Olawale and Sun, 2010) most of the studies, however, considered the two problems separately (Dakas et al., 2004). The causation factors are reviewed in the following subsections.

2.5.1 Factors triggering variability of project costs

Oraegbune (2008) outlined factors responsible for construction cost and time overruns in some of the federal government owned projects in Yola; Adamawa State in Nigeria. The factors include variations to original scope of work, late payment of/refusal to honour interim certificates, fluctuations and inflation, remeasurement of provisional sums, late delivery of imported construction materials, client's interference, lack of relevant design details, contractor's weakness in implementing cost control measures, lack of co-operation among project participants, client's lack of confidence and dissatisfaction with the contractor, foreign content in mechanical installations, challenges of material importation and late release of mobilization by the client.

Many studies on construction project performance across the globe focus mainly on the causes (Abd-El-Razek et al., 2008; Gbahabo and Ajuwon, 2017). Some of these studies and study areas are listed in Table 2.3 with nine of the studies conducted in Nigeria between 1998 and 2012, apart from those in Asia and other advanced economies.

Table 2.2: Past cost overrun studies

S/No	Author	The Study	Study Area
1.	Dlakwa and Culpin (1990)	Reasons for overrun in public sector construction projects in Nigeria	
2.	Ogunbiyi (1992)	Risk management and construction project cost overrun.	
3.	Elinwa & Buba (1994)	Construction cost factors in Nigeria.	Nigeria[3]
4.	Al-Juwairah (1997)	Factors affecting construction costs in Saudi Arabia.	Saudi Arabia[1]
5.	Achuenu and Kolawole (1998)	Assessment and modelling of cost overrun of public building projects in Nigeria	
6.	Gundiri (1998)	Cost overrun of public building projects (A case study of former Gongola and the Adamawa States)	
7.	Mbachu and Olaoye (1999)	Analysis of major cost overrun factors in building project execution.	Nigeria[6]
8.	Baloi and Price (2003)	Modelling risk factors affecting construction cost performance	Mozambique
9.	Flyvbjerg et al. (2004)	What causes cost overrun in transport project.	Covered 20 nations
10.	Iyer and Jha (2005)	Factors affecting cost performance: evidence from Indian construction projects.	India[1]
11.	Azhar et al. (2008)	Cost overrun factors in the construction industry of Pakistan.	Pakistan
12.	Lee (2008)	Cost overrun and cause in Korean social overhead	Korea

S/No	Author	The Study	Study Area
		capital projects: Roads, rails, airports and ports.	
13.	Nega (2008)	Causes and effects of cost overrun on public building construction projects in Ethiopia.	Ethiopia
14.	Ali and Kamaruzzaman (2010)	Cost performance of construction projects in Klang Valley	
			Jordan[1]
15.	Ameh et al. (2010)	Significant factors causing cost overruns in telecommunication projects in Nigeria.	Nigeria[7]
16.	Chileshe and Berko (2010)	Causes of project cost overrun within Ghanaian road construction sector	Ghana
17.	Memon et al. (2010)	Factors affecting construction cost performance in project management: Case of MARA large projects.	Malaysia[1]
18.	Ramabodu and Verster (2010)	Factors contributing to cost overruns of construction projects	South Africa
19.	Kasimu (2012)	Significant factors that cause cost overrun in building construction project in Nigeria.	Nigeria[8]
20.	Durdyev et al. (2012)	Factors causing cost overruns in the construction of residential projects; case study of Turkey.	Turkey
21.	Memon et al. (2012a)	The causal factors of large project's cost overrun: A survey in Southern part of Peninsular Malaysia.	Malaysia[2]
22.	Arcila (2012)	Avoiding cost overruns in construction projects in the United Kingdom.	UK
23.	Ade et al. (2013)	Controlling cost overrun factors in construction projects in Malaysia	Malaysia[4]
24.	Mahamid & Dmaidi (2013)	Risks leading to cost overrun in building construction from consultants' perspective	Palestine
25.	Rahman et al. (2013b)	Significant factors causing cost overrun in large construction projects in Malaysia	Malaysia[5]
26.	Sweis et al. (2013)	Cost overruns in public construction projects: The case of Jordan	Jordan[2]
27.	Amoa-Abban and Allotey (2014)	Cost overruns in building construction projects: A case study of Accra-Ghana	Ghana[3]
28.	Allahaim and Liu (2015)	Causes of cost overruns on infrastructure projects in Saudi Arabia	Saudi Arabia[2]
29.	Mbachu and Cross (2015)	Key drivers of discrepancies between initial and final costs of construction projects in New Zealand	New Zealand
30.	Aljohani et al. (2017)	Construction projects cost overrun: what does the literature tell us?	17 nations

Key: Nigeria[8] = 8 studies in Nigeria, Malaysia[5] = 5 studies in Malaysia, Ghana[3] = 3 studies in Ghana etc

Construction project performance is seemingly well researched (Baloyi and Bekker, 2011), with different survey methods adopted, including intensive literature reviews, questionnaires and interviews with practitioners and experts (Wiguna and Scott, 2005). Fourty-three (43) cost overrun driving factors were identified from the literature. By scholars' citation frequency and using the basis of contractual party's responsibility, they are classified into the main contractor, client/consultant, macroeconomic and project, subcontractor/supplier, procurement system and general factors. As shown in Table 2.4, by frequencies (by counting), 32% (14 of factors) lie in the main contractor's contractual responsibility while 21% (9 of the factors) are in client/consultants' areas of control. The others are macroeconomic/political 14% (6 factors), general factors 12% (5 factors), project peculiarity 9% (4 factors), and suppliers/subcontractors 7% (3 factors). The last 5% (2 factors) are classified as related to the procurement system. It can thus be inferred from scholars' findings that the main contractor ordinarily has the highest share of construction cost overrun control.

Table 2.3: The classification of construction cost overrun factors under the controlling contractual party

Cost overrun factor & the controlling contractual party	Researcher
Contractor	
Inaccurate estimates/tender sum, contractor's improper contract knowledge, poor management of construction programme, poor cost/financial management, inadequate planning, contractor's inability in risk/uncertainty management, schedule delay, inadequate project monitoring/ evaluation/control, payment delay to subcontractor/supplier, contractual claims and poor cost control system, rework due to mistakes, shortage of labour, delay in equipment supply, ineffective contract management, poor site management and fraudulent/corrupt practices.	Aghimien et al. (2017), Alaghbari et al. (2007), Ali and Kamaruzzaman (2010), Aljohani et al. (2017), Al-Juwairah (1997), Al-Khaldi (1990), Ayodele (2010), Azhar et al. (2008), Azis et al. (2013), Cantarelli et al. (2010), Elinwa and Buba (1994), Frimpong et al. (2003), Harisaweni (2007), Iyer and Jha (2005), Koushki and Kartam (2004), Jennings (2012), Jarkas (2016), Lee (2008), Le-Hoai et al. (2008), Memon et al. (2010), Morris (1990), Nega (2008), Olawale and Sun (2010), Omoregie and Radford (2006), Oseghale and Olugbenga (2008), Peters and Madauss (2008), Rahman et al. (2013b), Ramabodu and Verster (2010), Shanmugapriya and Subramanian (2013), Sriprasert (2000), Stephen (1997), Subramani (2014), World Bank (2012),
Client and consultant	
Lack of relevant information and details, cash flow problems, delay in stage payments to the main contractor, design changes and errors, discrepancy/deficiency in contract documents, non-adherence to contract conditions, inadequate prime cost and provisional sum, contract information delay, changes in specification, poor financing and variation to works.	Alaghbari et al. (2007), Aljohani et al. (2017), Ameh and Osegbo (2011), Ameh et al. (2010), Al- Azhar et al. (2008), Azis et al. (2013), Enshassi et al. (2009), Le-Hoai et al. (2008), Mbachu and Cross (2015), Memon et al. (2010), Morris (1990), Najjar (2008), Nega (2008), Olawale and Sun (2010), Omoregie and Radford (2006), Oseghale and Olugbenga (2008), Rahman et al. (2010), Subramani (2014).
Macroeconomic and political	
Unstable local currency value/exchange rate, government's change in policy and fiscal measures, weak regulation and control, fluctuation and inflation of prices, high interest rate, economic instability, general insecurity and fuel shortage.	Alaghbari et al. (2007), Al-Najjar (2008), Altshuler and Luberoff (2003), Ameh and Osegbo (2011), Azhar et al. (2008), Cantarelli et al. (2010), Enshassi et al. (2009), Le-Hoai et al. (2008), Iyer and Jha (2005), Frimpong et al. (2003), Kaming et al. (1997), Elinwa and Buba (1994), Mahamid and Dmaidi (2013), Memon et al. (2010), Morris (1990), Mosey (2009), Nega (2008), Rahman et al. (2013b).
Project	
Complexity, size of work, location, environmental restrictions, undefined and unclear scope, unforeseen site and soil conditions.	Al-Khaldi (1990), Al-Momani (2000), Abdelgawad and Fayek (2010), Ameh and Osegbo (2011), Azis et al. (2013), Le-Hoai et al. (2008), Okmen and Oztas (2010), Olawale and Sun (2010), Nega (2008), Iyer and Jha (2005), Morris

Cost overrun factor & the controlling contractual party	**Researcher**
	(1990).
Procurement system	
Tendering method and contract system	Al-Khaldi (1990), Azhar et al. (2008), Iyer and Jha (2005), Mahamid and Dmaidi (2013), Morris (1990).
Subcontractor and supplier	
Shortage/delay in material supplies, non-performance of subcontractors, low-quality materials	Azhar et al. (2008), Morris (1990), Olawale and Sun (2010), Sriprasert (2000).
General cost overrun factors	
Conflicts between contractual parties, external parties' influence, lack of communication between parties, lack of coordination of project parties, industrial unrest/strikes	Iyer and Jha (2005)

Ahiaga-Dagbui et al. (2015), and Jain and Singh (2012) describe the literature which has proposed several explanatory models on the subject as static, stagnant and replicative. The models, according to Jain and Singh (2012) lack predictions on how cost overruns behave over time in terms of frequency and magnitude. Scholars' models have all failed to address several important issues like how the cost overruns vary with the size and types of projects. The authors addressed those lapses in their cost overrun theory, which states in four parts that (i) cost overrun declines over time; (ii) is relatively high for procurement involving construction projects, compared to procurement of finished products, such as machinery; and (iii) within construction projects, more complex projects experience higher cost overruns compared to less complex ones. Lastly, (iv) in contrast to the existing literature on incomplete contracts, an increase in the probability of renegotiation can increase the asking price by the bidding contractors.

2.5.2 Project time variability triggering factors

Concern for construction project time overrun is also evident from the research conducted globally about it. Some of thesestudies are listed in Table 2.5. Researches on time overrun cut countries countries as the UK, USA, Korea, Hong Kong, India, Thailand, Malaysia, Saudi Arabia, Pakistan, Egypt, United Arab Emirates, Tanzania and Ghana. Solutions are still being proferred, based on the identified causes.

Table 2.4: Previous studies of time overruns

S/No	Author	The study	Study area
1.	Bromilow (1969)	Contract time performance expectation and the reality	Australia
2.	Baldwin et al. (1971)	Causes of delay in the construction industry.	United States of America[1]

S/No	Author	The study	Study area
3.	Arditi et al. (1985)	Reasons for delays in public projects	Turkey[1]
4.	Amer (1994)	Analysis and evaluation of delays in construction projects in Egypt	Egypt[1]
5.	Assaf et al. (1995)	Causes of delay in large building construction projects	Saudi Arabia[1]
6.	Chan and Kumaraswamy (1995)	A study of the factors affecting construction durations in Hong Kong	Hong Kong[1]
7.	Nkado (1995)	Construction time-influencing factors: The contractor's perspective	UK[1]
8.	Chan and Kumaraswamy (1996)	An evaluation of construction time performance in the building industry	Hong Kong[2]
9.	Ogunlana et al. (1996)	Construction delay in a fast-growing economy: Comparing Thailand with other economies	Thailand
10.	Odeyinka and Yusif (1997)	The causes and effects of construction delays on completion cost of housing projects in Nigeria.	Nigeria[1]
11.	Chan and Kumaraswamy (1997)	A comparative study of time overruns in Hong Kong construction projects.	Hong Kong[4]
12.	Abd-Majid & McCaffer (1998).	Factors of non-excusable delays that influence contractors' performance	U K[2]
13.	Mbachu (1998)	Construction duration of institutional building projects Nigeria	Nigeria[2]
14.	Mezher and Tawil (1998)	Causes of delays in the construction industry in Lebanon	Lebanon
15.	Al-Khali and Al-Ghafly (1999)	Important causes of delay in public utility projects in Saudi Arabia.	Saudi Arabia[2]
16.	Al-Momani (2000)	Construction delay: A quantitative analysis.	Jordan[1]
17.	Ishaya (2000)	Analysis of time overrun in North-eastern Nigeria highway projects	Nigeria[3]
18.	Noulmanee et al. (2000)	Internal cause of delay in highway construction project in Thailand.	Thailand
19.	Elinwa and Joshua (2001)	Time-overrun factors in Nigerian construction industry	Nigeria[4]
20.	Ahmad et al. (2002)	Delays in Construction: A brief study of the Florida construction industry	Florida[1]
21.	Odeh and Battaineh (2002)	Causes of construction delay: Traditional contracts	Jordan[2]
22.	Syed et al. (2002)	Construction delay in Florida: An empirical study	Florida[3]
23.	Choudhury and Phatak (2004)	Correlates of time overrun in commercial construction	Texas, USA[2]
24.	Mobarak (2004)	Analysis and evaluation of delays in construction projects in Egypt	Egypt[2]
25.	Assaf and Al-Hejji (2006)	Causes of delay in large construction projects.	Saudi Arabia[3]
26.	Acharya et al. (2006)	Investigating delay factors in the construction industry: the Korean perspective.	Korea
27.	Aibinu and Odeyinka (2006)	Construction delays and their causative factors in Nigeria	Nigeria[5]
28.	Faridi and El-Sayegh (2006)	Significant factors causing the delay in the UAE construction industry.	United Arab Emirate (UAE)[1]
29.	Lo et al. (2006)	Construction delays in Hong Kong civil	Hong Kong[5]

S/No	Author	The study	Study area
		engineering projects.	
30.	Alaghbari et al. (2007)	The significant factors causing a delay in building construction projects in Malaysia	Malaysia[1]
31.	Sambasivan and Soon (2007)	Causes and effects of delays in Malaysian Construction	Malaysia[2]
32.	Abd-El-Razek et al. (2008)	Causes of delays in building construction projects in Egypt.	Egypt[3]
33.	Oseghale and Olugbenga (2008)	Reasons for delay in building projects: A case study of Edo State, Nigeria.	Nigeria[6]
34.	Sweis et al. (2008)	Delays in construction projects: The case of Jordan.	Jordan[3]
35.	Al-Kharashi and Skitmore (2009)	Causes of delays in Saudi Arabian public sector construction projects.	Saudi Arabia[4]
36.	Hamzah et al., (2009)	Finance related causes contributing to project delays	Malaysia[3]
37.	Saleh et al. (2009)	Causes of delay in the construction industry in Libya	Libya
38.	Abdullah et al. (2010)	Causes of delay in MARA (Majlis Amanah Rakyat) management procurement construction projects	Malaysia[4]
39.	Fugar and Agyakwah-Baah (2010)	Delays in building construction projects in Ghana.	Ghana
40.	Mohammad (2010)	The factors and effects of delay in government construction projects: A case study of Kuantan University, Pahang Malaysia	Malaysia[5]
41.	Pathiranage & Halwatura (2010).	Factors influencing the duration of road construction projects in Sri Lanka.	Sri Lanka
42.	Soliman (2010)	Delay causes in Kuwait construction projects	Kuwait
43.	Ameh and Osegbo (2011)	Study of the relationship between time overrun and productivity on construction sites	Nigeria[7]
44.	Ayudhya (2011)	Evaluation of common delay causes of construction projects in Singapore.	Singapore
45.	Haseeb et al. (2011)	Problems of projects and effects of delays in the construction industry of Pakistan	Pakistan[1]
46.	Pourrostam and Ismail (2011)	Significant factors, cause and effects of delay in Iranian construction projects	Iran[1]
47.	Doloi et al. (2012)	Analyzing factors affecting delays in Indian construction projects	India
48.	Jeykanthan and Jayawardena (2012)	Cost escalation and scheduled delays in road construction projects in Zambia.	Zambia
49.	Kikwasi (2012)	Causes and effects of delays and disruptions in construction projects in Tanzania	Tanzania
50.	Aziz (2013)	Ranking of delay factors in construction projects after the Egyptian revolution.	Egypt[4]
51.	Fallahnejad (2013)	Delays in Iran gas pipeline projects	Iran[2]
52.	Gündüz et al. (2013)	Quantification of delay factors using the relative importance index method for construction projects in Turkey	Turkey[2]
53.	Rahshid et al. (2013)	Causes of delay in construction projects of	Pakistan[2]

		Punjab-Pakistan: An empirical study	
54.	Sunjka and Jacob (2013)	Significant causes and effects of project delays in the Niger Delta Region, Nigeria.	Nigeria[8]
55.	Hasan et al. (2014)	An investigation into delays in the road project in Bahrain.	Bahrain
56.	Kadiri and Shittu (2015)	Causes of time overrun in building projects in Nigeria: Contracting and consulting perspectives	Nigeria[9]
57.	Taha et al. (2016)	A model for evaluation of delays in construction projects	Covered 4 nations; Egypt[5], Saudi Arabia[5], United Arab Emirates[2] and Qatar
58.	Akhund et al. (2017)	Time Overrun in Construction Projects of Developing Countries	Pakistan[3]

Key: Nigeria[9] = 9 studies in Nigeria, Egypt[5] = 5 studies in Egypt, Hong Kong[4] = 4 studies in Hong Kong, etc

Studies on the time overrun challenge date back to 1969 when Bromilow in Australia investigated contract time performance expectation. Others like Bromilow (1969), who conducted similar studies in Nigeria, include Aibinu and Odeyinka (2006), Elinwa and Joshua (2001), Kadiri and Shittu (2015), Mbachu (1998), Odeyinka and Yusif (1997), Sunjka and Jacob (2013), yet construction project time overruns continue unabated. The causes of project time overrun identified from literature and the contractual party who is responsible for those factors, are outlined in the Table 2.6. A total of 49 construction time factors interplay at the construction stage, causing delays which are invariably corrected by an extension of time. By scholars' citation frequency, the main contractor shares 43% (21), client/consultants 27% (13), macroeconomic 12% (6), project 12% (6), general factors 12% (6) and suppliers/subcontractors 6% (3). It can be inferred from scholars that most causes of time overrun are the responsibility of the main contractor, which implies that the contractor has the largest share in the control and limitation of time overruns. The next most responsible party is the client/consultants, then the project peculiarity in terms of design, its size and location, then the macroeconomic/community factors, the subcontractor and supplier-related activities, and other general factors.

Table 2.5: Classification of time overruns factors under the controlling contractual party

Time overrun factor & party responsible	Researcher
Contractor's responsibility	
Inaccurately estimated construction programme and poor management, inadequate planning and scheduling, ineffective resource co-ordination, lack of relevant tools and equipment, poor labour productivity, inadequate communications, lack of appropriate software, unclear and inadequate instructions to operatives, shortage of labour, rework due mistakes, site accidents, payment delays to subcontractors and suppliers, poor site management and supervision, contractor's inexperience, obsolete/unsuitable construction equipment, poor project management, unclear	Abd-El-Razek et al. (2008), Ahmed et al. (2003), Aiyetan et al. (2012), Al-Khalil and Al-Ghafly (1999), Baloyi and Bekker (2011), Divya and Ramya (2015), Doloi et al. (2012), Frimpong et al. (2003), Haseeb et al. (2011), Jarkas (2016), Kadiri and Shittu (2015), Kaming et al. (1997). Kikwasi (2012), Koushki et al. (2005), Long et al. (2004), Abd-Majid & McCaffer (1998), Memon et al. (2010), Ng et al. (2001), Odeh and Battaineh

Time overrun factor & party responsible	Researcher
and inadequate instructions to operators, programme/schedule delay, contract manager’s inexperience, inability in risks and uncertainty management, financial problems, industrial unrest/strikes, unforeseen site/soil conditions, inadequate project monitoring and contractor’s improper contract knowledge.	(2002), Ogunsemi and Jagboro (2006), Olawale and Sun (2010), Sambasivan and Soon (2007), Taha et al. (2016),
Client and Consultant	
Variations, client's undue interference, changes in specifications, design changes and errors, contract information delay, lateness in drawings submissions, delay in inspections and testing of completed works, payment delays to main contractor, client's slowness in decision making, bureaucracy in client's organization, corruption and fraudulent practices, delay in drawing preparation and approval, delay in building permit approval, incomplete technical documentation, lack of coordination of project parties and fraudulent/corrupt practices.	Ahmed et al. (2003), Al-Momani (2000), Ayudhya (2011), Divya and Ramya (2015), Kadiri and Shittu (2015), Kikwasi (2012), Koushki et al. (2005), Memon et al. (2010), Ogunsemi and Jagboro (2006), Sambasivan and Soon (2007).
Project	
The complexity of works, unforeseen site and soil conditions, accidents, undefined and unclear scope.	Kaliba et al. (2009), Kikwasi (2012), Koushki et al. (2005), Ogunsemi and Jagboro (2006), Olawale and Sun (2010).
Macro-Economic and Community issues	
Insecurity or insurgency, unstable and high-interest rate, fuel problems, industrial unrest, political instability, insurgency and insecurity, force majeure and civil commotion/community issues.	Kaming et al. (1997), Kikwasi (2012), Memon et al. (2010), Ogunsemi and Jagboro (2006),
Supplier and Subcontractor	
Non-performance, late delivery of materials, subcontractor non-performance.	Baloyi and Bekker (2011), Haseeb et al. (2011), Kikwasi (2012), Ogunsemi and Jagboro (2006), Abd-Majid & McCaffer (1998).
General factors	
Lack of communications between parties, natural disaster as flood, the conflict between contractual parties, inclement weather and act of God.	Ayudhya (2011), Choudhury and Phatak (2004)

Ogunlana et al. (1996) in Thailand and Kaming et al. (1997) in Indonesia concluded that the blame for most project delays lay with the contractor. Abd-Majid and McCaffer (1998) categorized 50% of the delays as peculiarities of construction projects and inexcusable delays, for which the contractors were responsible. Aljohani et al.’s (2017) study corroborated earlier research findings by concluding that most of the causes of overruns were related to poor resource management of the project contractor.

2.5.3 Construction stage dual (cost and time) overruns: triggering factors

Adu and Ekung (2017) emphasised the interrelationship between three major construction project performance criteria (cost, time and quality) saying that failure in any affects the others (Adu and Ekung, 2017). For example, schedule delay results to cost overrun factor (Dlakwa and Culpin, 1990; Enshassi et al., 2009; Omoregie and Radford, 2006 and Shen, 1997). The assertion is supported by Baloyi and Bekker (2011), Rahshid et al. (2013), Sambasivan and Soon (2007) who argue that overrun factors do not stand alone, the ultimate cost overrun results in multiple factors which contribute to the final construction cost differential. Additional work ordered by the client usually results in programme delay, first in ordering material which in the meantime is subject to price increases. Items omitted from the engineer's estimate of the projects due to design errors or inadequate scope, frequently result in change orders, which increase construction cost, as well as time of delivery (Shrestha et al., 2013). Time overruns or delays invariably contribute to cost overruns (Baloi and Price, 2003; Chan and Kumaraswamy, 2002; Mbachu, 1998; Odeh and Battaineh, 2002). As noted by Frizelle (1993), money and time are inextricably linked, and the consequences are considerable when durations are longer.

Several construction target-influencing factors drive both initial construction cost and duration of projects simultaneously. The cumulative effect is wide gaps between the tender sum/initial duration and final account/actual construction duration. Listed in Table 2.7 are factors influencing project cost and time overruns simultaneously. They are grouped under the responsibility of contractor, client and consultants, sub-contractor/suppliers, project peculiarity and general factors. Analysis of the foregoing shows firstly, that 43 factors and 49 factors influence the bill of quantities contract sum and the estimated construction duration respectively. It can be seen in the survey instrument (Appendix IV) that the last 26 factors on the cost and time list of drivers are replicated. This implies that the factors exert influences on both cost and duration targets simultaneously. As seen in the same Table 2.7, variation to works, contract information delay, and payment delays to the main contractor are variables that influence project cost and duration target at the same time (Aziz, 2013; Haseeb et al., 2011; Iyer and Jha, 2005; Jeykanthan and Jayawardena, 2012). Moreover, items omitted from the project estimate due to design errors or inadequate scope frequently result in change orders. These increase cost as well as the time of delivery (Shrestha et al., 2013). The percentage of these dual cost and time factors in both constructs is between 53% and 60%.

The foregoing justifies a holistic approach to research in construction project overrun challenges, in a single study rather than separate studies because of some factors which exert influence on both cost and time targets. Nevertheless, several authors across the globe had combined the two challenges in a single study; their emerging recommendations do not seem to have had a significant impact on the poor performance of construction projects. Some past studies in a combined cost and time performance on construction project include Adam et al. (2014), Agren et al. (2011), Al-Najjar (2008), Alinaitwe et al. (2013), Apolot et al. (2015), Baloyi and Bekker (2011), Borse and Khare (2016), Bromilow (1974), Chang (2002), Dakas et al. (2004), Dlakwa and Culpin (1990), Elinwa and Joshua (2001), Enshassi et al. (2009), Frimpong et al. (2003), Harisaweni (2007), Kaliba et al. (2009), Kaming et al. (1997), Koushki et al. (2005), Le-Hoai et al. (2008), Long et al. (2004), Love et al. (2015), Mansfield et al. (1994), Memon et al. (2012b), Merrow and Tarossi (1990), Moura et al. (2007),

Table 2.6: Classification of dual construction cost and time overrun factors in the controlling contractual parties

Singular cost and time drivers & party responsible	Author and factor classification	
	Cost	Time
Contractor's responsibility Payment delay to sub-contractors and suppliers, contract manager's inexperience, contractor's inability in risk and uncertainty management, poor labour productivity, poor site management, cash flow problems, reworks due to mistakes, shortage of skilled labour, fuel shortage, industrial unrest/strikes, unforeseen site/soil conditions, inadequate project monitoring, contractor's improper contract knowledge.	Azhar et al. (2008), Cantarelli, et al. (2010), Elinwa and Buba (1994), Frimpong et al. (2003), Morris (1990), Wiguna and Scott (2005).	Agyakwah-Baah (2010), Al-Momani (2000), Amer (1994), Chan and Kumaraswamy (1997), Abd-El-Razek et al. (2008), Fugar and Agyakwah-Baah (2010), Haseeb et al. (2011), Jeykanthan and Jayawardena (2012), Mansfield et al. (1994), Mezher and Tawil (1998), Pathiranage and Halwatura (2010), Sambasivan and Soon (2007), Sepasgozar et al. (2015), Soliman (2010), Wiguna and Scott (2005).
Client and consultants Variation to works, contract information delay, payment delays to the main contractor, changes in specifications, design changes and errors (rework), lack of coordination of project parties	Iyer and Jha (2005)	Al-Momani (2000), Assaf et al. (1995), Aziz (2013), Chan and Kumaraswamy (1997), Faridi and El-Sayegh (2006), Fugar and Agyakwah-Baah (2010), Haseeb et al. (2011), Jeykanthan and Jayawardena (2012), Pathiranage and Halwatura (2010), Sambasivan and Soon (2007).
Sub-contractor and suppliers Non-performance, delay in the delivery of imported materials,		Al-Khalil and Al-Ghafly (1999), Amer (1994), Arditi et al. (1985), Baldwin et al. (1971), Abd El-Razek et al. (2008), Faridi and El-Sayegh (2006), Jeykanthan and Jayawardena (2012), Mansfield et al. (1994), Sweis et al. (2008),
Project peculiarities Project size and complexity	Bhargava et al. (2010), Bordat et al. (2004), Odeck (2004), Jahren and Ashe (1990)	Morris (1990)
General factors Lack of communication between parties, conflict contractual conflict between parties, poor weather conditions	Bhargava, et al. (2010), Chan & Kumaraswamy (1997)	Chan and Kumaraswamy (1997) Abd-Majid and McCaffer (1998), Morris (1990).

Odediran et al. (2012), Olawale & Sun (2010), Omoregie and Radford (2006), Otunola (2008), Ramanathan et al. (2012), Shanmugapriya and Subramanian (2013), Singh (2010), Ubani et al. (2015), Wiguna and Scott (2005), Yakubu and Ming (2009), Zujo et al. (2010). These studies reveal an ongoing and global concern about the poor performance of construction projects.

Secondly, the bulk of cost and time influence factors (see Tables 2.4, 2.6 and 2.7) predominantly lie in contractor's responsibility. This aligns with the findings of Frimpong et al. (2003), Rahman et al., (2013b), Zujo and Car-Pusic (2008); yet contractors are either unable to control or manage the driving factors and the resultant influences (Wiguna and Scott, 2005). Aje et al. (2009), Enshassi et al. (2009), and Le-Hoai et al. (2008) submitted that poor site management ranked first among cost overrun factors in Vietnam, and as a significant cost overrun factor in Pakistan. The authors added that the performance of the contractor is paramount to the success of projects, because it is the party that converts the design into reality, therefore, it is primarily the contractor’s management capability that sustains project performance. Thirdly, the analysis shows that successful treatment of the overruns contributed by factors under the control of contractor (32% for cost and 43% for duration constructs) can result in more than a quarter of the desired solutions, according to the research in construction cost and time performances (Abam et al., 2017; Rahman et al., 2013b).

Moreover, the literature reveals that existing studies on construction project cost and time overruns are heavily skewed towards causative factors (Gbahabo and Ajuwon, 2017). Again, the literature shows that site managerial strategies for prevention and mitigation currently have little consideration for machine learning process. Therefore, knowledge improvement in that area is vital for financial and construction material resource planning, as a precaution against the negative consequences of poor project performances.

Despite the volumes of research efforts, the problems have remained unabated (Ameh and Osegbo 2011; Love et al., 2015). Notwithstanding the benefits derived from cost and time control techniques and advent of computer project management software, many construction projects still do not achieve their cost and time objectives (Ahiaga-Dagbui et al., 2015; Flyvbjerg, et. al., 2003a; Olawale and Sun, 2010). Cost overrun exists globally over the years and it has not decreased; it appears no learning seems to take place concerning the subject (Ahmad et al., 2002; Flyvbjerg et al., 2014). Awolesi et al. (2015) revealed that there is a significant difference between initial contract sum and the final account of building projects; even where some mitigating measures were considered, the author concluded that the problem of cost and time overrun was seemingly intractable. Overrun studies have largely stagnated in the refinement and advancement of the knowledge area. As noted earlier, the bulk of it has largely been replicative, remarked (Ahiaga-Dagbui et al. 2015). The situation is unhealthy for public buildings which are executed with limited government funds (Aghimien et al., 2017) considering the strategic role of the construction industry. Supposedly, on this basis Ahiaga-Dagbui et al. (2015) are suggesting a significant and methodological paradigm shift from the investigation of causation factors to information and communication forecasting techniques to effectively address the perennial and complex problem of poor performance in construction delivery.

Moreover, there is a dearth of studies that considered the construction stage influence of both cost and time drivers, especially on the factors that exert dual influences on the cost budget and estimated construction duration. This research takes one step forward over previous studies by attempting to answer the questions posed on the persistence of overruns in the construction industry. Also, the study is a response to Memon et al.'s (2010) proposition that keeping construction projects within estimated costs and schedules requires sound strategies, good practices and careful judgment. The study seeks to discover (i) the extent to which past studies have eased the challenges; (ii) why the overruns are still prevalent in the global construction industry, and even on the increase, despite research efforts; and (iii) to conceptualize the essential strategy for bridging the existing knowledge gap. The simultaneous influence of some factors on both cost and time objectives suggests a combination of the two challenges in a single study for effective diagnosis. This study, therefore, sourced data on public (government) buildings to determine the influence of the driving factors, with a view to developing impact prediction models for project cost and construction duration. The construction cost and duration drivers established from related literature are summarized in the following section.

2.6 Summary of cost and time overrun factors

Frequent owner-desired changes coupled with inherent uncertainties and complexities, financial, economic, environment in which most projects are performed, have made their completion on schedule and budget a difficult task to accomplish. Construction project planners though not unaware of that fact hardly consider influence of these factors while planning for cost and time. Projects that considered the impact of construction-stage intervening variables at inception are noted for high cost predictive precision. The estimating process though difficult, exhausting and futile, the difficulty is due to a complex web of factors. Ignoring them altogether also creates a perfect recipe for future overruns, because a high level of uncertainty surrounds most project poor performance causation factors at inception. These factors are synthesized and presented in Tables 2.4, 2.6 and 2.7 earlier in this Chapter and discussed under the research constructs in Chapter Four.

Some of these construction stage cost and time drivers influence both ways (dual influence on both cost and time). These are; variation to works, inadequate planning and scheduling, inadequate prime cost and provisional sum, contract information delay, payment delays to main contractor, payment delays to sub-contractor and supplier, contract manager's inexperience, changes in specifications, design changes, design errors, contractor's inability to manage risks and uncertainties, poor labour productivity, cash flow problems, project complexity, lack of communication between parties, non-performance of sub-contractors, conflict between contractual parties, rework due to mistakes, shortage of labour, fuel shortages, industrial unrest/strikes, delays in the delivery of imported materials, unforeseen site/soil conditions, lack of co-ordination of project parties, inadequate project monitoring, contractors' improper contract knowledge, fraudulent and corrupt practices.

It can be concluded that out of the 77 cost and time factors intervening at project execution stage, 26 (34%) of them exert double influence (simultaneously on cost and time) in addition to the 17 (22%) other factors influencing project tender sum and 34 (44%) factors on planned duration. The factors were used in the design of a questionnaire administered to construction project experts to source vidence for the prevalence of the various factors. A sample of the questionnaire is presented in Appendix IV.

2.7 The assessment of the influence and impacts of construction project cost and time factors

Influence is a measurable attribute; the capacity of one variable to affect another variable. Impact is the tangible measure of the consequences of the influence of one variable on another. While influence is only an intangible effect, impact is tangible, and it results from an intangible. Drawing from Oni's (2013) explanation of motivation as a variable, levels of which can be identified as low, moderate or high motivation; cost and time driving factors influence and impacts on the objectives of a construction project can also be measured. For example, in building constructions, a rainy day's influence on the construction programme is describable with terms as mild or intense, intermittent or continuous downpour. The impact (result) of the rain on the duration of an activity as outdoor concrete casting could be work hold-up. This impact is operationalized as a ratio of the number of man-days or man-hours in which the activity was delayed on the original schedule. From the foregoing, influence is, therefore, a qualitative variable operationalized by assigning score values as in the Likert scale. It is these values of influences and impacts of factors that formed the dependent and independent variables of the expected prediction models in this study. The impact by intervening variables on the construction cost and time performance illustrated in the following Table 2.8, using the Adamawa State projects executed between 1981 and 1996 (Oraegbune, 2008).

Table 2.7: An illustration of construction project cost and time performance computations

S/No	Project cost and duration					Cost and duration impacts	
	ID No	Cost (₦m)		Duration (months)			
		Initial	Final	Initial	Actual	Cost	Duration
1.	SP 1	56.91	151.27	4	44	1.66	10.00
2.	SP 2	22.00	134.00	9	228	5.09	24.33
3.	SP 3	15.50	28.03	6	60	0.81	9.00
4.	SP 4	309.00	431.00	3	--	0.39	Abandoned
5.	SP 5	42.00	800.00	36	228	18.05	5.33
6.	SP 6	1.00	6.00	18	60	5.00	2.33
7.	SP 7	1.64	25.55	6	129	14.58	20.55
8.	SP 8	7.50	84.92	24	160	10.32	5.67
9.	SP 9	0.86	47.76	6	-	54.53	Uncompleted

S/No	Project cost and duration					Cost and duration impacts	
	ID No	Cost (₦m)		Duration (months)			
		Initial	Final	Initial	Actual	Cost	Duration
10.	SP 10	0.95	4.20	7	48	3.42	5.86
11.	SP 11	2.47	4.42	8	11	0.79	0.50
12.	SP 12	19.96	26.88	6	36	0.35	5.00
	Total	479.79					

Source: Adapted from Oraegbune (2008: 39)

Poor performances were recorded on all completed projects (SP 1 – SP 12), which overran their budgeted cost and schedule completion periods. Factors that interplayed while works were in progress included late release or lack of funds by the state government, delay in payments of interim certificates, government bureaucracy, and schedule delays, variations to the original scope of work and design errors. These factors caused the differentials between the initial and actual targets. The ratio of the differences between the initials and finals on the initials and estimated outcomes (cost or time) are computed as impact (Odeyinka et al., 2012). Project SP 1 for example, the final cost ₦151.27m rose from the initial contract sum of ₦56.91m; the overrun translated to a cost impact of 1.66 computed as follows; 151.27 – 56.91/56.91 = 1.66

Similarly, 10.00 is computed as the impact on duration. In the same vein overruns or impacts can be computed individually for the remaining projects. Impacts, as used in the study, differ from Merrow et al.'s (1988) measurement of project cost growth and schedule slippage, in which the authors used the ratio of the cost estimate to the actual project cost, and ratio of planned to actual time. Influence of cost and duration factors for this study can be operationalized using a Likert scale of scores ranging from 0 to 5. These values are the levels of influence on cost/time during the project execution. In this context 0 represents no influence on cost/time; 1, a very low influence on cost/time; 2, a low influence on cost/time; 3, a moderate influence on cost/time; 4, a high influence on cost/time; and 5, a very high influence on cost or time.

2.8 Modelling the relationship between variables

Model specification is a process of identifying and operationalizing suspected variables that best explain the phenomenon being modelled (Morenikeji, 2006). In quantitative management techniques, the general approach is to set up a model which is a representation on paper that possesses certain properties of the project, system or organization of interest (Amusan et al., 2013a; Kirkham, 2007; Render et al. 1985; Vermande and Mulligen, 2000). The model might be a graph, a network, a table of values, a computer programme or a mathematical formula. Examples of graphical and mathematical models are; S-curve analyses, $\frac{C}{x} = \frac{a}{x} + b$, the Simple Keynesian model of an economy and Keynesian models of government including the foreign sector (Fellows et al., 2008, Mohr and Associates, 2015). By investigating the behaviour of the model, what happens in practice can be predicted to some extent, this assists in decision making (Adebayo et al., 2006 and Ameyaw et al., 2012). Fellows and Anita (2015) in categorizing models, used nomenclatures as material, logical, investigative, analogue, iconic, symbolic, replications, formalizations, simulations and predictive models.

2.8.1 Modelling techniques

The application of models to planning and managing new construction projects has been an object of interest to many researchers (Kaplinski, 1997; Lai et al., 2008; Lee et al., 2008) in the building and construction industry. Available statistical techniques for exploring relationships among variables on which models are normally built, are: correlation, partial correlation, multiple regression, logistic regression, factor analysis, structural equation modelling (SEM), partial least square structural equation modelling (PLM-SEM) and covariance-based structural equation modelling (CB-SEM). The use of simple correlation is limited to testing the strength and direction of relationship between pairs of variables. Partial correlations are useful in exploring the relationship between two variables while statistically controlling for a third variable. Logistic regression is used when the dependent variable is categorical, though it tests the predictive power of a set of variables and assess the relative contributions of each individual variable. Factor analysis generally is suitable for reducing many related variables to a smaller more manageable number of components before use in relationship modelling. Structural equation modelling (SEM) is a sophisticated quantitative methodology which enables researchers to simultaneously examine a series of interrelated dependence relationships between a set of constructs represented by several variables while accounting for measurement error (Wilson et al. 2014). The use of SEM, CB-SEM and PLS-SEM which alternative to each other are still at their early stages Wilson et al. (ibid). They are used for estimating theoretically established cause-effect relationship models. Although PLS-SEM has been designed as a predictive-oriented approach to SEM, its use is recently gaining popularity in the construction industry (Hair et al., 2012a; Hair et al., 2012b; Ringle et al., 2012).

A regression equation is an ordered mathematical statement which shows that two amounts are equal. Its purpose statistically is a presentation of an equation-like model depicting the pattern or patterns inherent in the dataset (Clark, 2018) used in determining the equation. Multiple regression which is much nearer to a real-life situation has been used. It allows for prediction of a single continuous dependent variable from a group of independent variables. It is thus used in testing the predictive power of a set of variables and assesses relative contributions of each individual variable and hence predictive models. Multiple-linear regression-based models are more commonly used by construction planners and estimators (See Table 2.9 for some series of multiple regression equations which are products of research) for predictions due to adaptability to data scales of measurement. As discussed in Section 2.8.2, their use in construction project cost-and- time estimating is fast becoming inappropriate.

Table 2.8: An overview of some multiple linear regression (MLR) forecast models

S/No	Regression model	Dependent variable	Author
1.	$L = K. CB$ or $\ln L = \ln K + B. \ln C$	Duration	Bromilow (1969)
2.	$Log\ L = Log\ C + b_1x_1 + b_2x_2 + \dots + b_6x_6$	Duration	Walker (1995)
3.	$Ln\ L = b_0 + b_1in\ C - x_1 + x_2 + x_3b_3 - b_4\frac{x4}{x5}$	Duration	Chan and Kumaraswamy (1999)
4.	$Y = 82.87 + 1.0016x$	Duration	Al-Moumani (2000)
5.	*Y = 14.439 = 13.377 ("concrete pump" transportation method) + -4.125 ("property" types of formwork) + -3.609 (productivity of erecting formwork to floor slabs) + 1.690 (number of supervisions)*	Duration	Proverbs & Holt (2000)
6.	$Y = 269C^{0.32}$	Duration	Chan (2001)
7.	$Log\ L = b_0 + b_1log\ CL + x_2 + x_3$	Duration	Skitmore & Ng (2003)
8.	*Y = 5.458 + (-6.403E – 02) DELAYEDT + 0.489LIFEEMP2 + 0.172CSTIME + 0.415PSUBCON2 + (-2003E – 03) DCARATI*	Duration	Xiao & Proverbs (2003)
9.	$\sqrt{L} = b_0 - b_1log\ C + b_2\ log^2\ C + b_3\ x_3 + b_4\ x_4 + b_5\ x_5 + b_6\ x_6 + b_7x_7$	Duration	BCIS (2004)
10.	*Y = 145 + 0.017 Gross floor area + 133 Contractors design capability OR Y = 3.462 + 0.024 gross floor area – 464 Project scope definition completion when bids are invited – 443 Extent to which the contract period can vary during bid evaluation – 180 Design completion when the budget is fixed*	Duration	Ling et al. (2004)
11.	$Log\ L = b_0 + b_1log\ x_1 + b_2\ log\ x_2$ *or* *log (t) = 3017.8 + 0.274 log (GFA) + o.142 log (floor);* *Where t = completion time; GFA = gross floor area, and floor = number of floors*	Duration	Love et al. (2005)
12.	*TPi = HCOi/PHi*	Duration	Moselhi et al. (2005)
13.	*Y = 25.37x – 110.27 Hospital Building* *Y = 47x – 238.7 Library*	Duration	Martin et al. (2006)
14.	*T = 118.563 – 0.401c (c > 408) or T = 603.427 * 0.610c (c >408)*	Duration	Ogunsemi & Jagboro (2006)
16.	*Ln L = b0 + b1 ln C – b2x2 – b3x3 – b4x4 –b5x5 – b6x6*	Duration	Hoffman et al. (2007)
17.	$Ln\ \frac{x1}{L} = b_0 + b_1\ ln\ x_1 - b_2x_2 - b_3ln\ x_3$	Duration	Stoy et al. (2007)
18.	$Fn = 0.524x_1 + 0{:}448x_2 + 0{:}001331x_3 + 46.986x_4 - 748956$ $Tm_t = 8{:}32 + 0{:}387x_1 - 0.00109x_2 + 0.898x_3$ $Tm_c = 7.481 + 0.912x_1 + 0.0000001749x_2 + 0.451x_3 + 0.00266x_4$ $Fs = 496366.157 + 0.005796x_1 - 0.001430x_2 + 0.964x_3$	Final cost & Duration & Final supply cost	Olatunji (2008a)

19.	*F. Cost = 216.57 – 12.24FAC15 + 7.26FAC4 – 24.98FAC11 + 8.77FAC1 + 4.28FAC7 + 2.22FAC6 – 5.58FAC8 + 2.76FAC5 +5.82FAC13 – 15.61FAC3 – 20.80FAC9 + 5.86FAC2 + 9.77FAC12 + 1.85FAC14*	Final cost	Ganiyu and Zubairu (2010)
20.	*T = 93.460 – 1.031PL*	Time overrun	Ameh and Osegbo (2011)
21.	*Y = 13.1159 + 1.1341x*	Duration	Aiyetan et al. (2012)
22.	*y = - 0.467 + 0.330x* *y = 28.292 + 0.057x* *y = 0.974 + 0.200x* *y = 25.728 - 0.21x*	Time overruns & cost overrun	Ijigah et al. (2012)
23.	*Percentage Cost Overrun = 0.214 + 0.046 (Financial condition of the owner) + 0.201 (Cash flow of contractor) + 0.345 (Method of procurement-open tender or selective tender) – 0.177(Material cost increase due to inflation) – 0.197 (Competition at tender stage-aggressive or not) – 0.108 (Fluctuation in currency) – 0.078 (Project size-small or large) – 0.284 (Delay in design and approval) + 0.08 (Risk retained by client for quantity variations) + 0.184 (Drawings-detailed or not) + 0.08 (Inaccurate material estimating)*	Percentage Cost overrun	El-Kholy (2015)
24.	*IC = 171.3 + 0.666H + 4.498nf - 0.000129A + 6.292S + 5.003str.* *where IC – predicted initial cost in USD/ft^2, H – height of one floor (12–18 ft.), A – area of building in ft^2, n_f – number of floors (1–3), S – sustainability index (1 for conventional and 2 for sustainable), Str – structure type (1 for concrete bearing wall steel and 2 for steel frame).*	Cost	Alhamrani (2017)

Linear regressions use the relationship between a dependent variable and sets of independent variables to predict or explain the behaviour of the dependent variable (Hair et al. 2010). Multiple linear regression models are generally represented in the form:

$y = a + b_1x_1 + b_2x_2 + \ldots b_nx_n$……………………………………………………Equation 2.1.

where *y* can be the total estimated cost or time (in the context of this study); $x_1, x_2 \ldots x_n$ are the measures of variables that are used to estimate *y*; and $b_1, b_2 \ldots b_n$ are the coefficients estimated by regression analysis and *a*, the estimated constant. The regression equation can then be used to predict the value of a dependent variable (cost or time impact) once the values of the independent variables (driving factors' influence) are inserted into the model (Clark, 2018). In Merrow and Tarossi's (1990) model, *y* is the estimated cost or actual cost and *x* the level of scope definition. Ameh and Osegbo (2011) constructed a predictive model for determining the impact of labour productivity on time overrun of construction projects in Nigeria, using a linear regression model, with labour productivity as independent variable and time overrun as the dependent variable. Aiyetan et al. (2012) modelled linear regressions of the relationship between the initial contract sum and final construction time, in South Africa. This study is emphasizing on the need for more appropriate technique for construction project cost and time planning, if the multiple linear regression techniques thitherto described as much nearer to a real-life situation and in use are again from recent studies found inappropriate.

2.8.2 Inappropriateness of mathematical regression models for construction resources

The first time-cost regression model in construction industry is attributed to an Australian researcher who, having analyzed cost and duration of a sample of construction projects completed during the late nineteen sixties, proposed a model, referred to as Bromilow's time-cost model (Kaka and Price, 1991). Since 1969 after the first construction project time-cost model (Bromilow Time-Cost model), the use of regression equations became popular globally for construction cost and duration forecasting. Developers of past regression models either for cost or construction activities durations include Aiyetan et al. (2012), Bromilow (1969), Chan and Chan (2004), Chan and Kumaraswamy (1999), Guerrero et al. (2014), Hammad et al. (2008), Hoffman et al. (2007), Love et al. (2005), Skitmore and Ng (2003), Stoy et al. (2007) and Walker (1995).

Multiple regression until recently was the best parametric technique for associating sets of variables such as final cost and actual construction duration with project outcome (Merrow et al., 1988; Chou and Tseng, 2011) and lately, differences between the actuals and the estimated. For the past six decades, they have been the best parametric and powerful tools, used as analytical and predictive techniques for cost estimating, because they have the advantage of a well-defined mathematical basis as well as measures of how well a curve matches a given dataset (Chou and Tseng, 2011; Kim et al., 2004; Tam and Fang, 1999). However, Kim et al. (2004), Tam and Fang (1999), noted the inappropriateness of regression analysis when describing multi-dimensional, non-linear (curvilinear) relationships, consisting of multiple input and output problems, as obtained in this study. Researchers are gradually acknowledging that discovery. For example, Ganiyu and Zubairu (2010:22) rightly acknowledged the weakness of multiple regression technique in their summary statement:

> The findings of their research showed that the major benefits of the neural network approach were the ability of neural networks to model the nonlinearity in the data. The model obtained gives a mean absolute percentage of error (MAPE) of 16.60% which includes a percentage (unknown) for client changes.

Ganiyu and Zubairu (2010:22) in that statement referenced Elhag and Boussabaine (2001: 2002) and Emsley et al. (2002) who applied the neural network approach to the prediction of total construction costs. Second, MLR has no specific or clearly defined approach that can be used to choose the model that best fits the historical data to a given cost estimating application (Adeli and Wu, 1998; Bode, 1998; Bode, 2000; Garza and Rouhana, 1995). Third, certain types of multiple equations and data are assumed to be suitable for multi-linear regressions (Adeli and Wu, 1998, Bode, 1998 and Bode, 2000). Fourth, the variables influencing the estimation must be reviewed in advance and it is difficult to use many input variables (Bode, 1998; Bode, 2000; Smith and Mason, 1997) like construction cost and time driving factors. Lastly, most model developers ignore the construction stage cost and time driving factors, except a few like Aiyetan et al. (2012), Baccarini (2006), El-Kholy (2015) and Skitmore & Ng (2003). The models do not take cognizance the influence of construction stage intervening factors such as variations to works (Ashworth and Skitmore, 1983; Achuenu, 1999), inflation, fluctuations in the prices of building materials, lapses in the supervisor's site allocations, the influence of weather and unforeseen soil conditions during constructions. Many of these variables are inevitable in constructions. The foregoing is one of the weaknesses Achuenu (1999) noted in seven of the regression cost prediction models developed between 1984 and 1995. The author remarked that their omission is a strong limitation of such forecasting models.

Moreover, Bromilow (1969) used estimated cost parameter instead of actual cost (final) as the independent variable in developing the first model. Guerrero et al. (2014), Kenley (2001), Ling et al. (2004), Love et al. (2005) argue that estimated cost was inappropriate for use as predictor variable, since cost at pre-contract stage usually differs from that at completion. Czarnigowska and Sobotka (2012) tagged the use of construction time-cost models built on estimated cost, an optimistic assumption, adding that the assumption is the foundation upon which the bulk of time-cost models are built. Also, Construction Task Force (1998) added that reliance on construction documents with which estimating models are built, w assume that the parameters already have the potential to cause differencess between what was intended and what was realized.

2.8.3 The unrelated basis of contingency fund estimations

Egwunatum and Oboreh (2015), Gunhan and Arditi (2007) described the mode of determining contingency allowances usually taken as cushions for accommodating the inevitable additional funds or time extensions always required in construction projects, as subjective (Egwunatum and Oboreh, 2015; Gunhan and Arditi, 2007), unreliable, and grossly inadequate (Otali and Odesola, 2014). Considerations used in their addition have no clear relationship with the numerous variables that impact on construction cost, or length of work at the site. Ameh et al.’s (2010) recommendation, in the light of this discussion, is not the blanket percentage addition to the project’s basic cost, but something he is trusting, that if evolved with scientific management principles, could help the current industrial and research status.

In conclusion, multiple linear regression is weak at forecasting construction cost and time objectives; allowances created to accommodate unforeseen contingencies are also inadequate due unrelated considerations with construction stage cost and time drivers. Following recent advancements in disciplines like medicine and marketing in terms of predictions with nonconventional **c**omputations, Construction Economists and Project Managers are exploring the merits of machine learning techniques. These are modelling systems which do not require the prerequisite establishment of rules and reasoning governing relationships between desired output and the significant input variables. The view of this research is that such systems are badly needed, especially in the construction industry of developing nations.

2.8.4 Computer software models

Predictive models are more valuable to construction project stakeholders for events forecasting. The most popular model in the field of construction engineering and the built environment, has been the MLR analysis technique. However, MLR analysis, whether in mathematical or computer programmes, has shortcomings that are now being noticed from recent research findings. In most disciplines, recently, there has been a paradigm shift from inputting known parameters into mathematical formulae for forecasting the unknown. Cost and time overruns are becoming synonymous with construction project performances in project management researches. One of the major factors is inaccurate cost and duration estimates (Aziz, 2013; Shah, 2016). Improved forecasting techniques are now being formed from relationships among variables which are used in the design of cost prediction models. These models are examined and checked for the level of fitness for purpose. Techniques for examining models coined from relationships among variables, include Partial Least Square-Structural Equations Modelling (PLS-SEM). Rahman et al. (2013a) used PLS-SEM to model causes of cost overrun in large construction projects in Malaysia. The shortcomings of the conventional multiple linear regression analysis as a forecasting technique are discussed in the following section.

Computer software models include spreadsheets with varieties like Microsoft Excel, Lotus 1-2-3, with facilities for tracking "what if" questions. Some more complex nonconventional computer software models for resolving issues quickly and more precisely include T395 Mechatronics Neural Networks, Mathematica, Maple R, MathCAD, Matlab, SPSS Neural Networks, R-Programming (Keeling and Rohani, 2008; Cortex, 2015). Neuroshell2 is a commercially available Artificial Neural Network (ANN) package produced by Ward Systems Group Inc. Other packages in the ANN system are R-Project for Statistical Computing, NeuroSolutions by NeuroDimensions Inc. for Excel 2002, and Trajan Neural Network Simulator Release 4.0E. The nonconventional computer software is classified as artificial intelligence (AI).

2.8.5 Artificial intelligence

Artificial intelligence is about how software can be used to process, analyze and extract meanings from natural language and process images and video to understand the world like humans do. An AI agent is any device that perceives its environment and takes actions that maximize its chances of successfully achieving its goals (Russell and Norvig, 2003). According to Stevenson (2012), society is already deep into a world where computers are ubiquitous and smart enough to handle some important tasks. An AI agent feels out the environment and uses the information to predict the outcome of new exploration. AI therefore deals with the theory and development of computer systems, able to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decision making and translation between languages. It is sometimes called machine intelligence or intelligence demonstrated by machines in contrast to natural intelligence displayed by humans and other animals. The goals of AI research include reasoning, knowledge representation, planning, learning, natural language processing, perception and ability to manipulate objects (Luger and Stubblefield, 2009). The AI field is founded on the claim that human intelligence can be precisely described for a machine to simulate. This led to research in machine learning to build predictive models, which can be extended to the construction industry, with immense benefit.

AI works by having large amounts of information fed into computer systems that identify patterns that humans would take impossibly long to detect. In the financial world, AI is already analyzing decades' worth of market data, Twitter sentiment and trading information to give fund managers a better grasp of when to buy and sell securities, or why one stock might be better than another. AI makes prediction easier; wherever companies face uncertainty in decisions, AI has the potential to support better decision-making (Ajay et al., 2018). AI is transforming other sectors like manufacturing operations which use AI-enabled self-learning programs on production lines. The healthcare sector relies on AI to analyze millions of data points, including information and research to help identify patterns in a variety of diseases. Many companies have been gathering data on their customers for years, and AI is changing how truly innovative companies can responsibly use data. Data about customers' past purchases, their clicks, and past calls on customer service can be actionable; knowledge can be extracted to deliver a much better experience. Artificial intelligence (AI) branches into computational creativity, fuzzy systems, evolutionary computation including evolution algorithms, genetic algorithm, and probabilistic methods, including: the Bayesian Network, the Hidden Markov Model and chaos theory. Other branches are machine learning (ML) comprising artificial neural networks (ANN) and hybrids of neural networks; case-based reasoning (CBR) and a support vector machine (SVM). Machine learning is a field of computer science that uses statistical techniques to give computer systems the ability to learn from data without being explicitly programmed. The name "machine learning" was coined in 1959 by Arthur Samuel (1901-1990).

- **a.** ANN is nonlinear model that is easy to use and understand, compared to statistical methods. ANN is a non-parametric model, while most statistical methods are parametric models that need a higher background understanding of statistics. ANN with back propagation (BP) learning algorithm is widely used in solving various classification and forecasting problems.
- **b.** ANNs are good for noisy datasets. The most important advantage of using an Artificial Neural Network is the ability to implicitly detect complex nonlinear relationships among variables. Such a characteristic makes the ANNs suitable for prediction and pattern recognition applications.
- **c.** ANNs are black-box modelling (this is their main disadvantage). One of the best advantages of ANNs is that they allow the modelling of physical phenomena in complex systems, without requiring explicit mathematical representations or exhaustive experiments.

2.8.5.1 Artificial neural network system

Artificial Neural Network (ANN) is a computational mechanism able to acquire, represent and map multivariate space information to another, given set of data representing that mapping (Fausett, 1994; Garrett, 1994). ANN processes information in a pattern like the human brain does (Gurney, 1997); it has an ability to derive meaning from complicated, non-linear and imprecise data. It can detect trends that are complex and hardly detected by other analytical tools (Sarle, 1994, Rafiq et al., 2001; Minin, 2006), can be used to provide projections given new situations of interest, and answer “what if” questions (Gunaydin and Dogan, 2004, Stergiou and Siganos, 2016). Other advantages of ANN include an ability to learn how to do tasks based on the data given for training or initial experience, creating its own organization or representation of the information it receives during learning, and carrying out computations in parallel (Haykin, 1994; 2010; Stergiou and Siganos, 2016). Neural networks have been used to solve a wide variety of tasks that are hard to solve using rule-based programming in various industries (Brass et al., 1994; Graves and Schmidhuber, 2009). Some construction industry researchers such as Kulkarni et al. (2017), Waziri et al. (2017), Mossalam and Mohamad (2017) ventured into ANN with recorded success, possibly considering Graves and Schmidhuber’s (2009) submissions. This research is of the view that the assessment of extensions of funds and time requirements should also be trialled on the ANN system, with a view to building cost-and-time assessment models. This is because a trained ANN works after a carefully selected previous example has been configured for specific application in a training and learning process.

Thus, a trained network can be thought of as an expert in the category of information it is given to analyze. Depending on the nature of the application and the strength of the internal data patterns, a network train quite well. This applies to problems where the relationships may be quite dynamic or non-linear. ANNs provide an analytical alternative to conventional techniques which are often limited by strict assumptions of normality, linearity, and variable independence (Alquahtani and Whyte, 2013; Bode, 2000; Ogunlana et al., 2000). ANN allows the user to quickly and relatively easily model phenomena which otherwise may have been very difficult or impossible to explain (Datt, 2012), and it can capture many kinds of relationships. Thus, ANN, which learns by example, can be used to recognize at inception the trends in final construction cost and the duration of public building projects, if carefully sourced historical influence and impact data are fed into the software as input and output variables. A typical artificial neural network consists of three groups or layers of units. A layer of the weighted input unit is connected to a layer of hidden units, in the network architecture depicted in Figure 2.1.

The activity of the input units represents the raw information that is to be fed into the network (independent variables) (Aibinu et al., 2015). The activity of the hidden unit is determined by the activities of the input units and the weights on the connections between the input and the hidden units, that is, the hidden layer through which the information is processed. The behaviour of the output units depends on the activity of the hidden units and the weights between the hidden and output units. The output layer is the layer in which the solution of the problem takes place, for example, prediction or classification. More complex systems for construction projects have more layers of input and output neurons (Chua et al., 1997). The weighted interconnections (synapses) store parameters called weights that manipulate the data in the calculations (Miller, 2015). The neural network is empirically derived rather than theoretical (Albino and Garavelli, 1998, Rafiq et al., 2001; Setyawati et al., 2002; Shtub and

Versano, 1999). The sum of all weighted inputs determines the degree of the activation level that is further modified by an activation function, to produce the output signal, expressed:

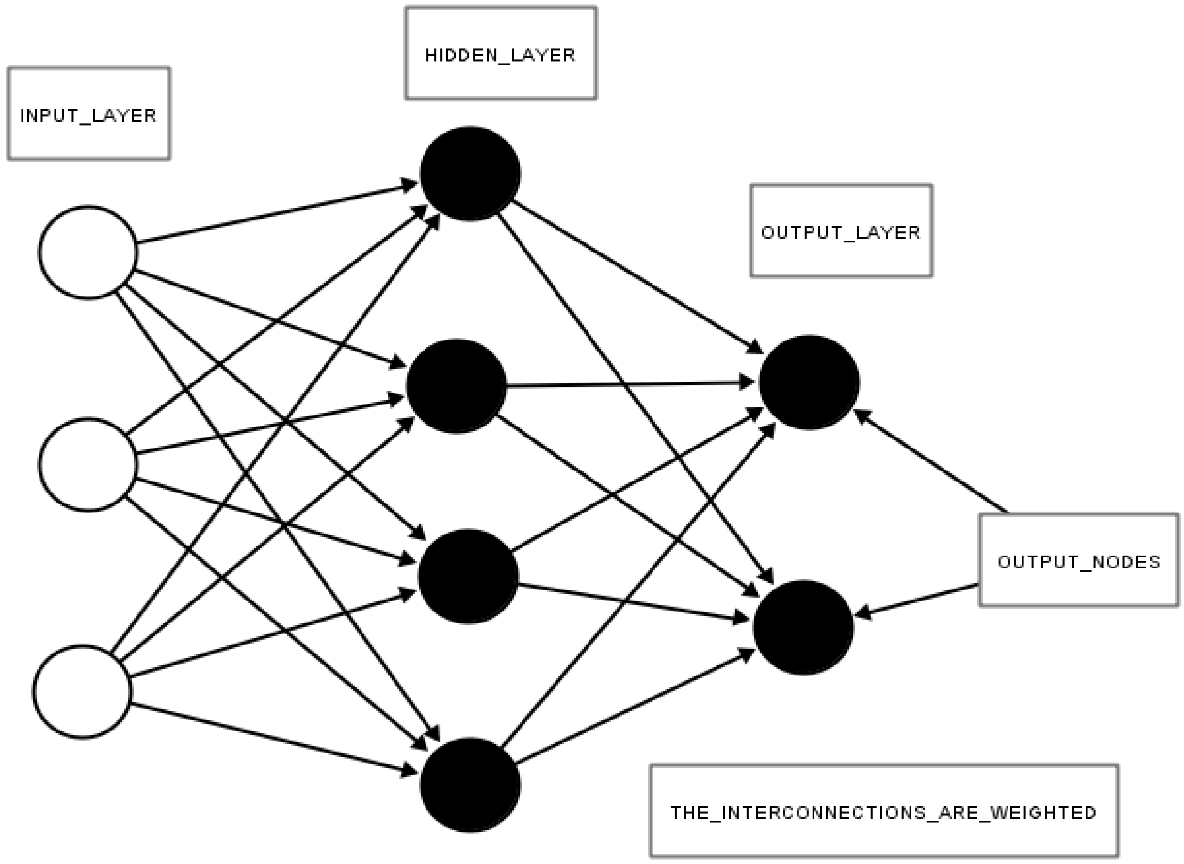


Figure 2.1: Typical artificial neural network architecture of 3 inputs, 4 hidden and 2 output neurons
(Source: Priddy and Keller 2005: 8)

Output 0 = f ($\sum_i WiXi$)...Equation 2.1

Where 0 = output; X_i and W_i = ith input and corresponding weight; and f = activation that can be a threshold function, or a smooth function like a sigmoid or a hyperbolic tangent function (Fu, 1994). Neural network models in artificial intelligence are usually referred to as artificial neural networks (ANNs); essentially simple mathematical models defining a function $f: X \rightarrow Y$ or a distribution over X or both X and Y (Werbos, 1975).

2.8.5.2 The Artificial Neural Network system in construction management

Studies that previously used neural networks as tool for prediction and optimization in construction management, for study purposes, include early cost estimation at design stage to provide architects and engineers with alternatives in cost planning (Aibinu et al., 2015; Al-Tabtabai et al., 1999; Gunaydin and Dogan, 2004; Squeira, 1999), and also estimation of cost of some building elements, such as reinforced concrete frames (Amusan et al., 2013a; Shtub and Versano, 1999). There are also studies that designed final construction cost or construction duration prediction models, namely those by Creese and Li (1995), Smith and

Manson (1997), Wang et al. (2012), and Petruseva et al., 2013). Recently, ANN is being used to predict project cost overruns and thereby assist management in developing an appropriate contingency (Chen and Hartman, 2000; El-Kholy, 2015). For example, Chua et al. (1997) used eight key project management factors to predict the final cost of construction projects. It was found that more than 90% of the examples did not differ by more than one degree of deviation from the expected outcome. Also, Chen and Hartman (2000) used ANN to predict the final cost of completed oil and gas projects from one organization, using 19 risk factors as the input data. It was found that 75% of the predicted final cost aligned with the actual variance; that is, where the ANN model predicted an overrun/underrun, an overrun/underrun occurred. Gunaydin and Dogan (2004) used eight design parameters to estimate the square metre cost of reinforced concrete structural systems in low-rise residential buildings and found that the ANN provided an average cost estimation accuracy of 93%.

Artificial neural networks can process a vast amount of data and make predictions that are sometimes surprisingly accurate (Sarle, 1994). This obviously is the reason why Doloi (2013) and Love et al. (2013) are suggesting statistical analysis of a set of actual projects with different characteristics to predict cost overruns. Also, Azis et al. (2013) called for researchers' adoption of proactive measures in the project planning stage, to predict and prevent cost overrun issues. Neural network systems ease modelling even when the functional relationships between input factors and project outcomes cannot be defined clearly; in addition, the model is also able to generate satisfactory solutions with incomplete and previously unseen data (Aibinu et al., 2015; Chua, 1997). However, back propagation neural networks (and many other types of networks) are in a sense the ultimate black boxes and their knowledge acquisition process is time-consuming (Creese and Li, 1995, Li, 1995, Boussabaine, 1996, Hegazy et al., 1994; Hegazy and Ayed 1998, Yeh, 1998a). Apart from defining the general architecture of a network and perhaps initially seeding it with a random number, the user has no other role than to feed it with input and watch it train and await the output. With back propagation, the user does not know any details of the process. Some software packages like NevProp, bp, and Mactivation do allow for sampling the networks' progress at regular time intervals, but the learning itself progresses on its own. The final product of this activity is a trained network that provides no equations or coefficients defining a relationship (as in regression) beyond its own internal mathematics; the network is the final equation of the relationship.

In Australia, Aibinu et al. (2015) used neural networks for cost estimation at the design stage to provide architects and engineers with alternatives in cost planning. Wang et al. (2012) in Taiwan used ANN to design final construction cost and schedule prediction models. In Calgary, Chen and Hartman (2000) used ANN to predict project cost and time overruns to assist construction managers in developing appropriate contingencies. Some of the studies that explored the application of Artificial Neural Networks (ANNs) to improve the accuracy of cost prediction across the globe are shown in Table 2.10.

Table 2.9: Prediction studies with the artificial neural network

S/No	Author	Research title	Study area
1.	Creese and Li (1995)	Cost Estimation of Timber Bridges Using Neural Networks	West Virginia, U S A
2.	Chua et al. (1997)	Model for the construction budget performance: A neural network approach	U S A
3.	Chen and Hartman (2000)	A Neural Network Approach to Risk Assessment and Contingency Allocation	Calgary
4.	Seung & Sinha (2006)	Construction equipment productivity estimation using the artificial neural network model	U S A
5.	Amusan (2011)	Neural network-based cost predictive model for building works	Nigeria
6.	Ahiaga-Dagbui and Smith (2012)	Neural networks for modelling the final target cost of water projects	Scotland
7.	Odeyinka et al. (2012)	Modelling Risks Impacts on the Viability of Contract Sum and Final Account.	Ulsta in the United Kingdom (U K)
8.	Wang et al. (2012)	Predicting construction cost and schedule success using artificial neural networks ensemble and support vector machines classification models	Taiwan
9.	Petruseva et al. (2013)	Neural Network Prediction Model for Construction Project Duration	Federation of Bosnia and Herzegovina
10.	Aibinu et al. (2015)	Cost estimation for electric and power elements during building design: A neural network approach	Australia
11.	Abidoye & Chan (2017)	Modelling Property Values in Nigeria Using Artificial Neural Network	Hung Hom, Hong Kong.

In the developed economies, during the 1902, an alternative branch of artificial intelligence, neural networks (NN) was used as a viable alternative for estimating construction cost (Li, 1995, Adeli and Wu, 1998; Bode, 2000; Bode, 1998; Creese and Li, 1995; Garza and Rouhana, 1995; Yeh, 1998b). This is because ANNs eliminate the need to find a good cost estimating relationship that mathematically describes the cost of a system as a function of the variables that have the most effect on the cost of that system (Bode, 1998; Bode, 2000; Creese and Li, 1995, Garza and Rouhana, 1995, Li, 1995). ANN's characteristics make it particularly suited for final cost and duration predictions because of its ability to completely map the complex relationship existing among the dependent variables (cost and time impacts or overruns) and the many independent variables (the influencing factors). ANN works very well in situations that involve capturing associations or discovering regularities within a set of patterns, where the volume, number of variables or diversity of the data is very great and where the relationships among variables are vaguely understood or are difficult to describe adequately with conventional approaches (Rafiq et al., 2001; Minin, 2006; Sarle, 1994). The relationship among the initial targets of project cost and duration, series of intervening variables and final construction cost/duration fall in this complex category, making ANN a better analytical tool than any other techniques. More of the merits of ANN over multiple regression analysis (MRA) are the ability to accommodate large data input and generate less error between input and expected output, consistent output, output and input mapping, low variation error, and it is better suited for data that does not adhere to generally low order polynomial forms (Creese and Li, 1995; David and Seer, 2004; Dissanayaka and Kumaraswamy, 2007; Gagarin et al., 1999; Moore et al., 1999; Shtub & Versano, 1999; Squeira, 1999; Petruseva et al., 2013; Smith and Mason, 1997; Stergiou and Siganos, 2016).

Various researchers have used neural networks as a tool for prediction and optimization, in construction time estimation; there are yet a few applications that are domiciled in Nigeria, although Amusan et al. (2013a) used ANN to estimate the cost of reinforced concrete frames. Waziri et al. (2017) also noted that models produced with ANN have a high predictive ability, and possess similar advantages compared to analogous and feature-based methods for cost forecasting. This study takes advantage of the merits of ANN recorded in industrial and research improvements to conceptualize models for predicting cost and time impacts on the targeted variables. This study mined evidential data provided by project stakeholders, comprising planned and actual project cost, duration and the intervening variables. The ANN trained and learnt the relationship pattern among the datasets used in designing the study's cost and time impact prediction models. However, one drawback is the difficulty in understanding the reasoning behind a neural network's prediction and transferring into rules. The internal workings are like a black box (Boussabaine, 1996; El-Kholy, 2015; Hegazy et al., 1994; Li, 1995; Yeh, 1998b); the user is unable to tell how the network achieved its results, since its knowledge or programme is implicitly encoded as numerical weights distributed across the network. However, there are a few alternatives which develop rules and explain the reasoning process.

2.8.5.3 Prediction accuracies of artificial neural network models

The prediction accuracies of past ANN models are shown in Table 2.11. The minimum percent accuracy of 70% are found in some past ANN prediction models. For example, Gunaydin and Dogan's (2004) ANN model of a reinforced concrete structural system in low-rise residential buildings for estimating the square metre cost, provided a cost accuracy of 93%. ANNs are suitable for modelling variables with both a linear or non-linear relationship, which contrasts with the linearity (Aibinu et al., 2015) and other series of assumptions required of data in modelling with regression techniques (Aiyetan et al. 2012; Clark, 2018; Kim, 2004). Research on the application of ANN performance prediction often compares the accuracy of ANN with multiple linear regression, and in most cases, ANN produce more accurate predictions (Aibinu et al., 2015; Bode, 1998; Bode, 2000; Chen & Hartman, 2000; Creese and Li, 1995; Garza and Rouhana, 1995; Gunaydin and Dogan, 2004; Kim et al., 2004; Shtub and Versano, 1999; Smith and Mason, 1997; Sonmez, 2004; Squeira, 1999; Chen et al., 2013; Yeh, 1998a).

The prediction accuracies of MLR and ANN cost prediction modelling in past studies are compared in Table 2.12. It can be seen from the table that the mean absolute percentage error (MAPE) of ANN models is quite lower than those of multiple linear regression (MLR), implying high prediction ability. Moreover, the fuzzy nature of MLR's use could discourage designers from complete observations of the basic requirements of MLR technique. ANN simply requires preliminary data cleansing, input and output mappings only, without any mandatory algorithmic process chart. This is the characteristic that earns it the name of 'black box'.

Table 2.10: ANN Model precision accuracy

1	Chua et al. (1997) used eight key management factors to predict the final cost of construction projects; more than 70% differed by less than 1 degree of deviation from the expected cost.
2.	Elhag and Boussabaine (1998) used the artificial neural system for cost estimation of primary and secondary projects. The ANN model I and II achieved average accuracy percentages of 79.3% and 82.2% respectively.
3.	Al-Tabtabai et al. (1999) developed a neural network for estimating percentage increase in the cost of a highway project from baseline estimate. The work generated outputs reaching a mean absolute percentage error of 8.1%.
4.	Chen and Hartman (2000) used ANN to predict the final cost of completed oil and gas projects from one organization using 19 risk factors as input data. 75% of the predicted final cost aligned with actual variance.
5.	Gunaydin and Dogan (2004) used eight design parameters to estimate the square metre cost of a reinforced concrete structural system in low-rise residential buildings, and the ANN provided a cost accuracy of 93%.
6.	Kim et al. (2013) Compared Estimation Costs of School Building Construction Using Regression Analysis, Neural Network, and Support Vector Machine Methods. The regression model and neural networks model, with 20 test datasets gave a mean absolute error rates (MAERs) of 5.68 and 5.27 respectively. Therefore, the NN model performed more effectively than RA in estimating construction costs.
7.	Aibinu et al. (2015) modelled cost of engineering services (power wiring, light wiring and cable pathway) at the design stage. With ANN the predictive errors were 6.4, 4.5 and 4.5% respectively. Regression analysis (RA) was found unsuitable because the relationship between cost influencing variables and cost of engineering services are subtle and unknown.

Table 2.11: Comparison of ANN and MLR prediction accuracy

S/No	**Research title**	**Author and Year**	**Mean Absolute Percentage Error (MAPE)**	
			Regression Model (RM)	**Artificial Neural Network (ANN)**
1.	Cost estimating of structural steel framing.	Squeira (1999)	15%	11%
2.	Total direct cost	Squeira (1999)	21%	13%
3.	Cost of wall panels	Squeira (1999)	57%	18%
4.	Total construction cost prediction	Emsley et al. (2002)	20.8-27.9%	16.6%
5.	Construction cost estimation of residential buildings in Korea.	Kim et al. 2004	6.95%	2.97%

Pewdum et al. (2009) developed an Artificial Neural Network to forecast the final budget and duration of highway construction projects in Thailand using data for 51 highway construction projects between 2002 and 2007 and found that the developed ANN model with a Mean Absolute Percentage Error of 8.51% (MAPE) forecasts the duration for highway projects better than the current Earned Value Method with a mean absolute percentage error of 19.90% (MAPE).

Also, Petruseva et al. (2013) used the linear regression and ANN to develop models for the prediction of duration of building projects in Bosnia and Herzegovina using data for 75 building projects with a good predictive ability (coefficient of determination, $R^2 = 0.97$) and MAPE of 2.5%. Mensah et al. (2016) developed both regression and ANN for small span bridges and indicated that the developed ANN model is superior to a regression model in estimating the duration of bridge projects. Kaur (2016) prepared an ANN model for predicting the duration of the ongoing project in addition to conventional techniques of project planning. The absolute variance of the model's results was from 1.70 to 2.60. This is less than the variance calculated by use of the PERT network technique (3.8 to 7.80) in the cases studied. Therefore, it can be concluded that Artificial Neural Networks are more effective project management tools that can be used to effectively predict the impact of construction cost and duration driving factors on the targeted variables and hence aid project planners in taking adequate precautionary measures at inception.

2.9 Summary of construction cost and time performance and efficacies of MLR and ANN techniques

The huge capital expenditure on public buildings annually was brought to the fore from the perspective of budgets on public higher educational institutions, as well as the potential negative consequencies of overruns on cost and time budgets of construction projects. The industrial status of construction project cost and time performance and global research efforts expended on the challenges were highlighted. In addition, the imbalances between the volumes of studies on cost and time overrun challenges against the global poor performances of construction projects were reviewed. Overrun causation factors were discussed, with an illustration of the impacts and influences. In this Chapter, the precise advantages of artificial neural network technique that are adaptable to construction project cost and time performance assessments are described, since the current estimating techniques have their limitations or inappropriateness. Modalities for bridging the gap being identified, are founded on the concept of bringing those advantages to bear on the construction industry. These are discussed in the following chapter, Chapter 3 – the research conceptual framework.

CHAPTER THREE: THE RESEARCH CONCEPTUAL FRAMEWORK

3.1 Introduction

The chapter draws on the inappropriateness of multiple linear regression (MLR) analysis presented in the literature review (Chapter Two) in the discussion of the relationship between cost and time driving factors' influence and overruns. It is also examining the simultaneous actions of some driving factors on both cost and time targets. The chapter discusses the theory of cost overruns and the unaddressed aspects and highlighted a knowledge gap. The conceptualized models for bridging the identified knowledge gap aided by the insights gained from the existing literature are discussed.

3.2 Theory of cost and time overruns

Jain and Singh (2012) identified lapses in current literature on construction project cost and time performance and packaged the lapses in a four-part cost overrun theory. The theory states that cost overrun declines over time (ii) cost overrun is relatively high for procurement involving construction projects, compared to procurement of finished products, such as machinery; within construction projects, (iii) more complex projects experience higher cost overruns compared to less complex ones or uncomplicated projects. Lastly (iv) in contrast to the existing literature on incomplete contracts, an increase in the probability of renegotiation can increase the asking price by the bidding contractors. The third item of the theory addresses complexity which also influence cost and time targets (Gidado, 1996; Lyneis et al., 2001). Achuenu (1999), Jahren and Ashe (1990), Kodwo and Seth (2014), Merrow et al. (1988), Odeyinka et al. (2009), observed the correlation between project size and cost overruns. The authors observed that the larger the construction project, the higher the cost overrun (Cooke-Davies et al., 2011). The work of Shrestha et al. (2013) on 363 public construction projects addressed the third part of the overrun theory. The authors found that complex, long-duration projects have significantly higher cost and time overruns than smaller short-duration projects. The following subsections review construction project complexity.

3.2.1 Project complexity

According to Bertelsen (2014) the term comes up in science more and more, but scientists themselves seem to be a bit in doubt, to the extent that one of the fathers of complexity studies Edward N. Lorenz (1917-2008) did not even include the term in his comprehensive book titled THE ESSENCE OF CHAOS. Currently there is not yet a generally comprehensive accepted definition of complexity (Kauffman, 1991). Complexity is not a new science but a way of looking upon systems, complexity studies comprise the connection between things not the things themselves (Lucas, 2000). Construction project managers normally breakdown the activities involved in the construction to help in having a comprehensive understanding of smoothness and hitches from commencement to completion. The smooth transition from one stage to the other especially on the face of challenges are issues that contribute to complexities in construction projects. That explains the definition of project complexity by the Construction Industry Institute (CII, 2015) as the degree of interrelatedness between project attributes and interfaces, and their consequential impact on predictability and functionality.

3.2.2 Examples of complex construction projects

Projects are ordinarily classified by the size of the construction cost as large, complex or mega, other dimensions used are the physical nature and the impacts on the society (Altshuler & Luberoff, 2003). Merrow et al. (1988) may have used that yardstick to list the following as examples of complex or megaprojects; Pakistan hydroelectric project, Haipu in South America, James Bay in Canada, Trans Alaska Pipeline System (TAPS) and Argentina Centro-Oeste project. Others are refinery and petrochemical complexes in Indonesia, Texas and South Arabia; mining and minerals extraction projects as Correjon in Colombia, the Statfjord Platform in the North Sea, Australia's Cooper Basin Project, and Papua New Guinea's huge copper and gold mining complexes, nuclear power plants in many countries and Synthetic-fuels plants in South Africa, Canada and Colorado, basic infrastructure projects as shipping ports, airports, new cities and universities. Taylor and Ford (2008) added the following to the list of mega projects; United States Naval Littoral Combat Ship (Karp, 2007), Channel Tunnel connecting Great Britain and France (Kharbanda and Pinto, 1996), Boston Central Artery project (USS, 2000; USHOR, 2005) and United States Department of Energy's National Ignition Facility. Since some other criteria can used to define and explain the term complex or mega projects, it is important that works on the dimensions of construction project complexity are first discussed.

3.2.3 Dimensions of construction project complexity

Ten knowledge areas of construction project complexity dimension presented by the Project Management Institute (PMI, 2012) are scope, time, cost, quality, human resources, communication, risks, stakeholders, procurement and intergration. Kerzner and Belack (2010) stressed that project risk and product size, time frame (Olatunji, 2018), technology and budgetary concerns have high-impact complexity dimensions on cost estimation. The authors emphasized that the factors need more attention if unforeseen cost implications are to be avoided. Kaming et al. (1997) advocated earlier that the complexity of projects is the major reason for cost overrun as it could cause a domino's effect on all components of the project. Interdependency and dependency, uncertainty, clarity of goals, political influence and technology are some of the dimensions that determine the level of complexity (Baccarini, 1996; Bar-Yam, 2004; Kerzner and Belack 2010; Remington and Polack, 2007).

Complex construction projects are very vulnerable to tipping points. Tipping points are conditions when crossed make system behaviour to radically change performance or a set of conditions that separate two very different internally driven behaviour modes (Taylor and Ford, 2008). Tipping point dynamics can explain the time overruns in complex construction projects. Lyneis et al. (2001) found that causal feedback within systems cause projects to evolve overtime in ways that make their management difficult. For example, the average construction duration for American commercial nuclear power plants tripled from 1959 to 1988 (NRC, 1982). The mean cost and time overruns of the plants were 338% and 239% respectively [Nuclear Regulatory Commission (NRC), (1982)] and the Energy Information Administration (EIA, 1988). Olaniran et al. (2015) reported that ongoing megaprojects globally are facing 64% cost overrun. The authors' research findings indicate that complex interactions between project characteristics or complexity, people, technology, structure and culture contribute to cost overruns occurring. Nigeria's Ajaokuta Steel Project, despite its 28% progress recorded already a 1400% cost overrun (Olatunji, 2018). Taylor and Ford (2008) observed that in large or complex projects, the impacts of; overestimation (Evans, 2005), errors (Busby and Hughes, 2004), rework (Cooper, 1993; Gidado, 1996; Love et al., 1999, 2000, 2002), concealing rework (Ford and Sterman, 2003), schedule pressure (Nepal et al., 2006) and lack of knowledge transfer between projects (Cooper et al., 2002) can be magnified by feedback dynamics within the project.

3.2.4 Human capital dimensions of complexity in construction projects

The aspects of project complexity dimensions which should occupy the top position on the list of complexity dimensions is the human and machinery resource capacity content embedded in architectural, services and structural engineering designs of construction projects. These comprise the number, calibre and quality (education and health) of personnel commensurate with the designs and the expected quality. A construction project may require heavy or light plant, machinery and equipment (Edwards and Holt, 2009) depending on its location, which may impact on project quality, cost and time of delivery, as well as its level of complexity. This informs Flyvbjerg et al.'s (2003a) argument that the definition of a mega project differs depending on the geographical setting, thus what might constitute a mega project in a more rural area might not be considered as such in a metropolis. However, the complexity dimension of organizational capability is not included in the scholars' yardsticks. This is related to how capable (structurally and technically) an organization is in managing the project and delivering the required product. In other words, it is directly associated with the appropriate or inappropriate selection of project personnel (Remington and Polack, 2007; Remington et al. 2009). Herszon and Keraminiyage (2014) explain that the dimension of construction project complexity is related to the knowledge and experience of the construction firm. According to the scholars, the knowledge and experience dimension is related to how much knowledge and or experience a key decision maker or project manager has regarding all elements (parts or components) of the product and the work that needs to be done on the project. This can be summarized as intellectual capacity, demand and creativity in the management of the construction processes. In addition, buildings within a landscape may be complex or complicated depending on the quality and quantity of construction personnel required. The human resource dimension in terms of the expected product quality should go beyond knowledge and experience of construction managers, to the technicians and operatives. Currently, research on the quality of personnel in relation to construction project complexity is scanty. These include installation and equipment mounting and dismantling risks, education, training and experience of the technicians and operatives. These construction operational inputs of time, human labour, equipment handling risks, ordinarily may have been factored into the construction cost, the on-site health challenges of builders, engineers, quantity surveyors, supervisors, foremen, headmen and operatives which might bear on the complexity nature of the project. Complexity of construction projects has been analyzed in this study into three levels: largely complex, moderately complex and uncomplicated construction projects.

3.2.5 Levels of complexity in construction projects

The third part of Jain and Singh's (2012) theory of cost overrun states that more complex projects experience higher overruns (cost and time) than uncomplicated building projects. Uncomplicated means simple or straightforward solution, easily understood or easy to do, elementary; effortless, manageable, not complex, not complicated by something outside itself, painless, presenting no difficulty, plain sailing, simple, uncomplicated, undemanding, and uninvolved. The meaning of the word simple can therefore be drawn from the opposites of not difficult or hard, not complicated or complex. In terms of construction cost, the programme of construction and construction materials and techniques, less complex or uncomplicated projects cost less than large, complex or megaprojects. Construction durations of uncomplicated projects ordinarily would take shorter length of time, requires technology of constructions that is easily understood by site foremen and supervisors. Light instead of heavy mechanical equipment. Team leaders could simply be experienced technicians and technologists.

There is a dearth of literatures on construction project complexity classifications, a single overall complexity classification does not exist (Luo et al., 2017) however, Liang (2005) acknowledged that small projects should have at least a characteristic of project cost between 0.1 to 5million USD and construction duration of 14 months or less. Hass (2008) used construction cost and duration classification formula to classify projects into three (i) independent, those less than three months and less than $250k, (ii) moderately complex between three and six months, $250 - $750k, (iii) highly complex above six months and above $750k. Flyvbjerg et al. (2003b) reasoned cost overrun as strategic misrepresentation because complex projects are typically capital intensive. Following that assertion, complex or megaprojects are therefore projects requiring huge physical and financial resources like mammoth hydroelectric projects. The U.S Federal Highway Administration states that megaprojects are projects valued at more than One Billion United States dollar (USD) (FHWA, 2004). Although Merrow et al. (1988) added that in constant 1984 USA dollar, while other definitions as the number of total engineering or construction days are also possible and sometimes preferred. Memon et al. (2012a) in Peninsular Malaysia classified large projects as projects with a minimum contract sum of 5 million Malaysian Ringgit (RM), Altshuler and Luberoff (2003) and Flyvbjerg (2004) estimated the minimum contract sum as USD 250 million and USD 500 million.

Flyvbjerg (2004) argues that the definition of a mega project differs depending on the geographical setting, thus what might constitute a mega project in a more rural area might not be considered as such in a metropolis (Flyvbjerg, 2004). Scholars also upheld in Montequin et al. (2018) that complex projects are composed of multiple interrelated systems where changes in one system require unforeseen changes in the connected systems (Herszon and Keraminiyage, 2014; Shenhar and Dvir, 2007). Though there appears to be a strong indication that complex project using the construction cost size yields higher cost overruns, Merrow et al. (1988) and Hinze et al. (1991) stated that absolute value of cost overruns and schedule slippage increase with the size of projects, putting very large sums of money at risk. Thus, project complexity may cause poor project success.

3.3 Research question and the emerging hypothesis

Hitherto, overruns in cost and time have manifested in various types of construction projects, currently, there are no known North East (Nigeria) geopolitical zone-based studies on the comparison between the magnitude of overruns in complex and less complex projects. The investigations of complex project comparisons listed as part of the objectives of this study are anchored in the following research question and the emerging research hypothesis founded on the propositions listed Chapter One sections 1.3 and 1.7 of this report.

Research question (1); **how do the cost and time performance of uncomplicated, moderately complex and largely complex projects compare?**

Research question (2); **what are the impacts of project complexity on construction cost and time performance?**

Hypothesis (H_{1a}): there are significant cost and time performance differentials among uncomplicated, moderately complex and complex construction projects in the study area.

Hypothesis (H_{1b}): Levels of construction project complexities impact differently on cost and time performances.

3.4 The dual influence of some cost and time driving factors

An examination of the data collection instrument Appendix IV sections 3 (cost) and 4 (time) shows that 26 driving factors are reflected in the cost and time constructs. These include; variation to works, inadequate planning and scheduling, inadequate prime cost and provisional sum, contract information delay, payment delays to the main contractor, payment delays to sub-contractor and supplier. It implies that such factors exert influence simultaneously on both cost and time project objectives. For example, a project facing delay is usually extended or accelerated, both solutions have extra costs implied (Sambasivan and Soon, 2007).

By analysis; these dual influence factors constitute 60% i.e. (26/43 x100) of the cost constructs and 53% i.e. (26/49 x 100) of the time. The dual influence factors' contributions to project cost and schedule slippages should be accounting for about fifty percent variability between projects' initial targets and actual outcomes. Their influence mode is illustrated with Figure 3.1. Studies that corroborate that finding include Frimpong et al. (2003), Azhar et al. (2008), Baloyi and Bekker (2011), Bhargava et al. (2010), Cantarelli et al. (2010), Abd-El-Razek et al. (2008), Haseeb et al. (2011), Memon et al. (2010), Morris (1990), Sambasivan and Soon (2007), Singh (2010), Soliman (2010).

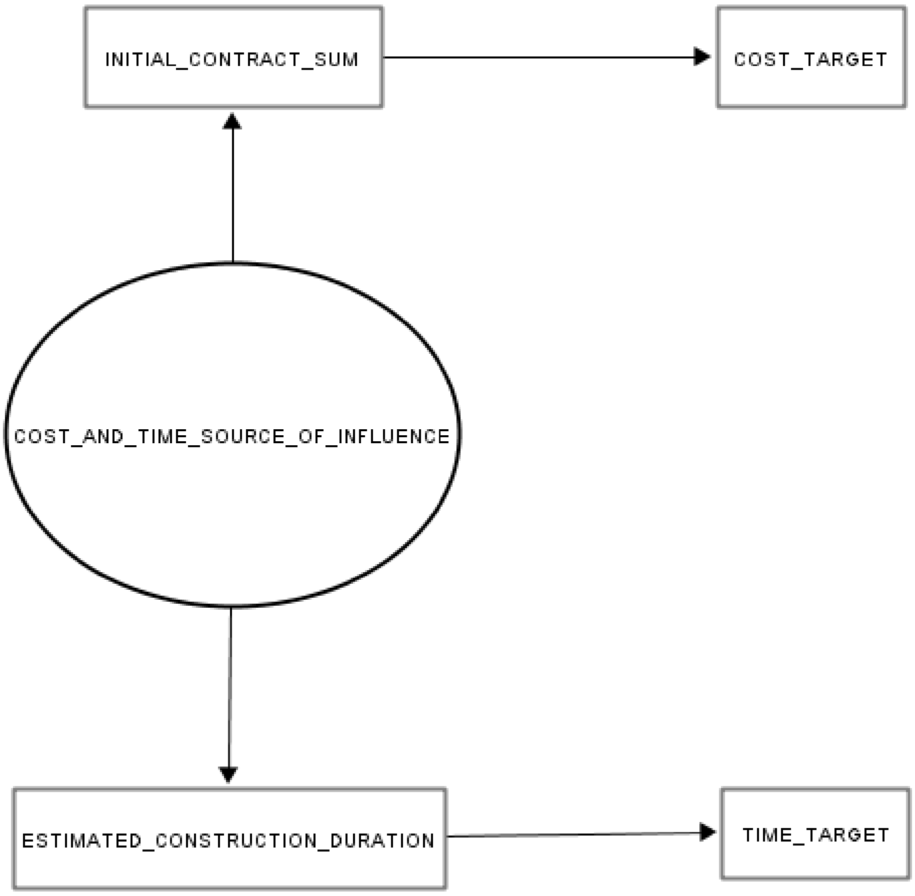


Figure 3.1: Dual influence of some factors on both cost and time targets

It can it can therefore be inferred from the foregoing that; to every amount of differential in construction cost, there is a corresponding schedule slippage and vice versa. Based on this, this study is of the view that; effective solutions to construction project poor performance can only be proffered from studies that treat construction project cost and time performance together in a single study and not in the usual separate single studies as usually conducted. Moreover, given the relationships between the cost/time impacts and multiple drivers' influence which researchers found non-linear (Odeyinka, 2003) or unknown in relationship, construction projects in terms of cost and time often perform pooly. Usual solutions to project cost and time deficits have always been extra funds and programme extensions where possible. Therefore, effective mechanisms for predicting and assessing construction projects inevitable extra funds and additional times are imperative. Ijigah et al., (2012) attempted project overruns predictions but used multiple regression analysis which are inappropriate for constructions (Kim et al., 2004). Consequently, modelling systems which do not require prerequisite establishment of rules, reasoning and algorithmic thoughts governing relationships between desired output and the input variables are the needed alternatives.

When the dual influence turns out in multiples at the project construction stage, the resultants are impacts on the cost and time budgets (Amoa-Abban and Allotey, 2014). The dual influence nature of some factors contribute significantly to the stochastic and unknown relationship between construction project cost and time impacts and the driving factors' influence discussed in this next section.

3.5 Relationship between cost and time impacts and influence of the driving factors

In construction contracts, the contractor's deployed resources (labour, plants, and material) for construction operations are eventually translated to cost (Seeley, 1995). The concept of cost in executing building projects entails every constituent of costs incurred in the project from inception to completion. Cost is also seen as the total financial liability of the client (Douglas and Peter, 1984). Globally, evidence abounds on the discrepancies between initial contract sum and final cost of construction projects (Magnussen and Olsson, 2005; Polonski, 2006; Potts, 2005; Wanjari and Dobariya, 2016; Zewdu and Teka, 2015). The same is true of variability between the estimated and actual construction durations (Akhund et al., 2017; Asmah, 2014; Divya and Ramya, 2015; Durdyev et al., 2017; Emam et al., 2014; Fallahnejad, 2013; Famiyeh et al., 2017; Kholif et al., 2013; Motaleb and Kishk, 2010; Odeyinka et al., 2012).

Construction duration is usually specified in the contract agreement, it either originates from client or accepted from the contractor as part of tenders. Planners normally derive the overall programme of constructions from available project information; the drawings, bill of quantities, method statements and specifications (Nkado, 1995) after matching with the contractor's operational strengths. The programme details are therefore the aggregated computions derived using the appropriate labour and plant production coefficients which are finally modified with the planner's previous experiences. The construction duration is one of the benchmarks used in assessing project performance and organizational efficiency. Timely completion of a construction project is a goal common to both the client and contractor, who suffer losses when projects are delayed in completion (Thomas et al., 1995). Ideally, successful projects are those completed within the agreed primary success goals of cost and schedule.

Since labour costs are related to activity durations, linear functions are expected on the wages/time graphs (Abdullah et al., 2009; Sunde and Lichtenberg, 1995). Nevertheless, project peculiarities and intervening factors cause variability between the targeted project objectives and actual outcomes. Some of such peculiarities and unforeseen variables include reworks, inclement weather, contractors' related management and financial challenges (Abd-Majid and McCaffer, 1998; Acharya et al., 2006; Morakinyo et al., 2015; Alinaitwe et al., 2013; Karunakaran et al., 2018; Ubani et al., 2015). In like manner, the value of executed works on site increases with increase in site productions, though unforeseen influences of the driving factors again interplay on the work scope changes, mistakes and reworks, unforeseen site and soil conditions to cause differentials between initial contract sum and final cost.

The influence of the cost drivers on a construction project thwarts the supposed linear relationship; eventuating to non-linear relationships, depending on the nature of the driving factors. The relationships between the differentials of the targetted construction and final cost with the multiple driving factors' influence as observed by Aibinu et al. (2015) and Kim et al.

(2004) are beyond simple or linear associations. Also, the situation between that of time differential and the drivers' influence are non-linear. Olatunji (2008a) describe the relationships as interwoven while Jain and Singh (2012) opine that, given the multiplicity and rippling effects of the cost drivers the relationship between initial contract sum and final cost is stochastic, especially with the influence of the multiple intervening variables taken together.

3.6 The stochastic impact of factors that influence construction costs and schedules

Etymologically, stochasticm is of Greek origin that describes a process or system that relates to random probability, lack of organization or in a state of disorder or guess. In probability theory, stochastic or random process is a mathematical object usually defined as a collection of random variables. The random variables are associated with or indexed by a set of numbers, viewed as points in time that give the interpretation of randomness. representing numerical values of some system randomly changing over time, such as the growth of a bacterial population, fluctuation of electric current, or the movement of gas molecule (Doob, 1990; Gagniuc, 2017; Gikhman and Vladimirovich 1996; Parzen, 2015). Randomness according to Adler and Taylor (2007), Chaumont and Yor (2003), Kallenberg (2002), Rosenblatt (1974), Stirzaker (2005) implies a no pattern or patterns in the system. Moreover, some of the intervening factors are natural occurrences known for their high degree of unpredictability, meaning their occurrences are without stable patterns or orders. Stochastic process occurs at the project construction stage because the cost and time drivers interplay (Odeyinka et al., 2012) randomly.

The corrective measures used on a delayed project are management strategies comprising delay tracking, programmes extensions, overtime payments and task work used in controlling imminent project time overruns. These management solutions in many instances also create other issues related to extra cost because of some of the factors that drive both cost and time objectives. For example, additional works adds to the budget as well as schedule time of completion. Alkass et al. (1996) found that many delay factors are often interconnected, meaning that a delay can be a consequence of one other delay, so also are the mitigating strategies result to the multiplicity of other issues of cost and time overruns. These explain why the estimated duration/actual duration curves of projects end up twisted to levels that cannot be deciphered because of the complex multiples of intertwined construction time driving factors.

Stochastic or random phenomenon occur in every other discipline as neuroscience, computer science, technology, and engineering and in financial market, many of which have already found matching research models as it affects the individual discipline. For example, in cell biology Bressloff (2014) developed the theory of continuous and discrete stochastic processes. With examples and models the author provided basis for overcoming hinderances possed by variable randomness in the context of cell biology. The work of Lande et al. (2003) regarding the examination of population dynamics in ecology and conservation recognized the stochastic fluctuation which create risk of extinction that is non-existent in deterministic models. Envisaging the fundamental consequences for both pure and applied ecology, the authors provide research innovative solution titled introduction to stochastic population dynamics. The works combined classical background material with a variety of modern approaches, illustrated with examples of bird, mammalian populations and insect communities. Currently demographic and environmental stochasticity models are available with statistical estimating methods from field data. Similarly, the work of Rosenblatt (1974) paved way for future work on random processes. In it, the difficulties of heavy technique and detailed measurement reflect the earlier theoretic discussions in which the ideas and problems were initially obscured.

The author resolved them by the provision of the probability theory in a discrete context. In geometry and probability, Adler and Taylor (2007) recast topics in random fields by following a completely new way of handling geometry and probability. The authors in a completely new approach to geometric problems in the study of random fields resolved the intertwined problems arising in geometry and probability. Chaumont and Yor (2003) in statistical and probabilistic mathematics provide a guide from their measure theory to random processes. Another innovation can be seen from the work of Stirzaker (2005) on stochastic processes and models, the author introduced simple stochastic processes and models as against the complexes for use in subsequent studies. The works of Kallenberg (2002) and Van-Kampen (2007) in foudations of modern probability and stochastic processes in physics and chemistry respectively today are reference materials on stochastic theory. The fact that employing multiple linear regression technique helps in the derivation of multiple regression forecast models is not in doubt. But that is only obtainable where a pattern of relationship exists in the dataset and not when the relationship pattern is either unknown or stochastic this makes imperative prediction technique that is beyond multiple regression (Webos, 1975).

Unlike the innovative method proposed by this research, earlier studies had no better model for the mathematical associations between variables than multiple regression, before the advent of ANN. Construction management researchers at that time, from 1980 to about 2000, (Kulkarni et al., 2017) had no other method to make predictions about construction cost and time outcomes. Interestingly, correlation coefficient is an important statistic in the results of relationship (correlation) tests that are normally conducted prior to the development of the linear regression models. As stated earlier, the correlation coefficient from the tests indicate the strength and direction of the relationship between the independent variables (influence of the driving factors) and dependent variables (the impacts). In other words, the magnitude of the correlation coefficients serves as basis for deciding weather to proceed further or not in the process of prediction model design. Attempt to develop regression models for construction cost and time performance impacts in this research in that wise was first investigated by the determination of the correlation coefficients between the dependent and independent variables. The investigation proceeded in the data analysis Chapter 5 with the following hypotheses which are based on sub questions of the main research question;

Research question (2a): What is the relationship between construction project cost overrun and the cost driving factors' influence?

Research question (2b): What is the relationship between construction project time overrun and the time driving factors' influence?

Hypothesis (H_{2a}): There is a significant direct relationship between construction cost-driving factors influence and construction cost impact (cost overrun) in the study area.

Hypothesis (H_{2b}): There is a significant direct relationship between construction time-driving factors' influence and construction duration impact (time overrun) in the study area.

Research question 3: What predictive model could be devised from the relationships for use assessing the impact of construction cost-and-time-influencing factors on public building project production performance in north eastern Nigeria?

Hypothesis H_3: The direct relationship between the intervening factors' influence and cost and time impacts can be used to design cost and duration impact assessment models within a certain confidence level.

3.7 Knowledge gap

The persistence of construction project cost and time overruns globally suggest the need for improvements on the mechanisms for predicting the impacts on the project cost and time objectives from the influence of unforeseen driving factors. The facts established from the related literature search in earlier sections bother on knowledge gap which serve as basis for researching into advanced methods of construction cost and time assessments. Firstly, the discovery of MLR's inappropriateness in forecasting construction project cost and duration (Kim et al., 2004), secondly the inability of the MLR models to incorporate the influences of cost and time driving factors in the predictions, thirdly the weaknesses of MLR in mapping multiple non-linear predictor variables (see section 2.7.1), fourthly dearth of empirical studies on the relationships between project cost/time impacts and the driving factors' influence. Lastly, sudden work stoppages on building sites and construction materials delays experienced in an insurgent zone as the research study centre.

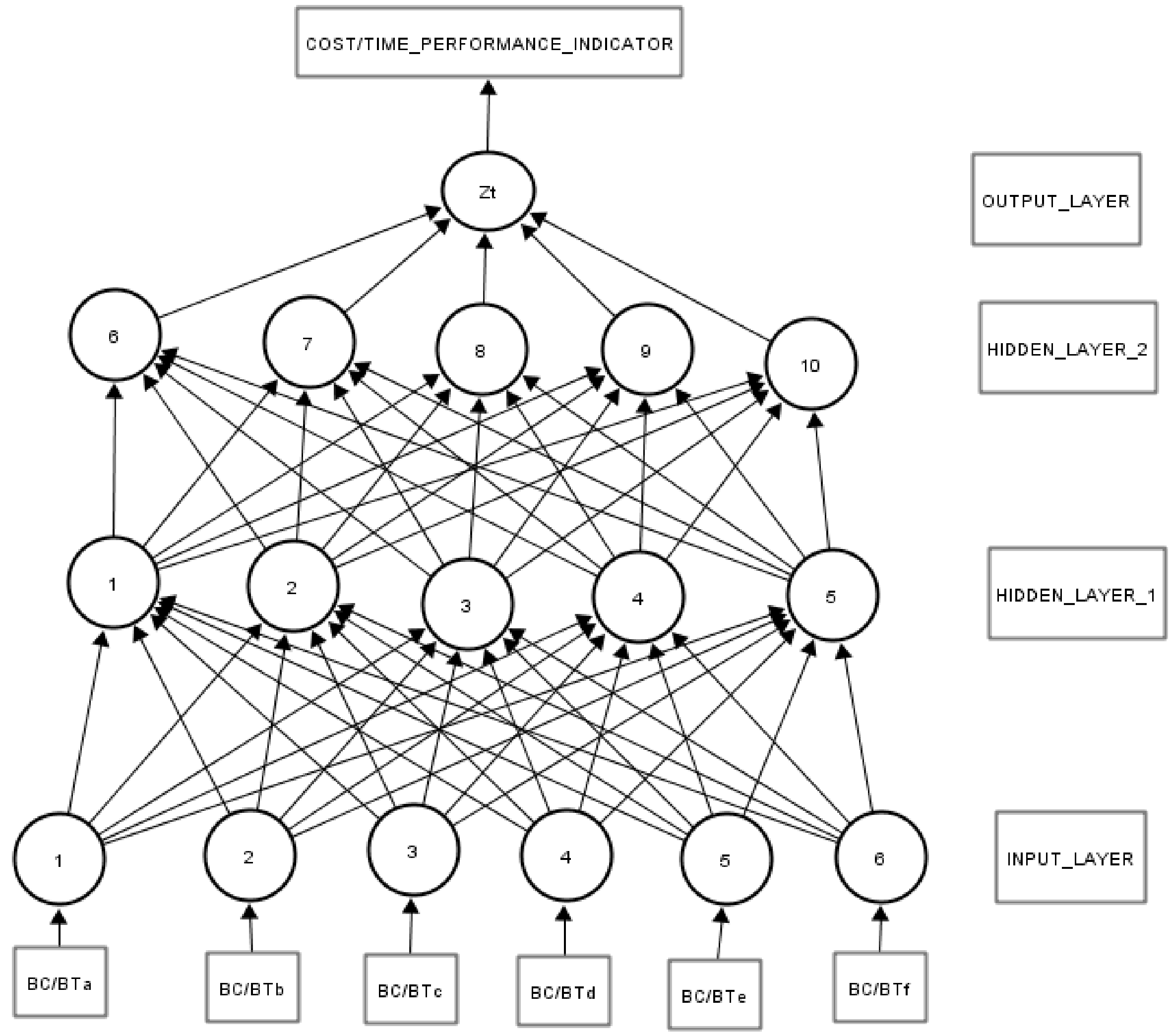
ANN overcomes the limitations of MLR and is adaptable for the prediction of impacts of cost and time factors' influence on building construction projects since its functionality is not impaired by any degree of association between the dependent and independent variables. Recall from the literature search that in artificial intelligence, stochastic programmes work using stochastic neural networks to solve problems of uncertainty. The technique build pattern from the given dataset across all manners of relationship including the non-linear and unknown relationships. It would therefore serve as alternative technique to multiple linear regressions in construction project management use of multiple non-linear predictor variables. That advantage has not been brought to bear sufficiently in the construction management research, most especially in the less developed economies as Nigeria. According to Squeira (1999) ANNs can capture real life experiences (stochastic relationship between the dependent and independent variables) encountered in constructions projects, generalizes and utilizes that knowledge for forecasting the inevitable additional cost over and above the bills of quantities' estimates as well as time extensions on the agreed construction programme length. Thus, unlike in the other disciplines where models are now available for treating problems of stochastics relationships, currently the building and construction management has a knowledge gap. This is the incomplete mapping of the relationship among the construction cost-time impacts and the multiple influence factors because of the stochastic phenomenon existing.

This research is of the view that cost and time impact prediction models can be developed by leaning on the probabilistic method of stochastic neural network that exist in artificial intelligence system to bridge the current knowledge gap. Like it was mentioned in section 2.8.1 there are other estimating techniques like SEM, CB-SEM and PLS-SEM, though the use of SEM is still at its early stage (Wilson et al., 2014). The same condition holds for both CB-SEM and PLS-SEM which are alternatives to each other. They are used for estimating theoretically established cause-effect relationship models. Though PLS-SEM has been designed as a predictive-oriented approach to SEM, their use is recently gaining popularity in the construction industry (Hair et al., 2012a; Hair et al., 2012b; Ringle et al., 2012). MLR and ANN only are selected for this study first because MLR is the current most popular technique among construction project resource estimators (Chou and Tseng, 2011; Kim et al., 2004; Merrow et al., 1988; Tam and Fang, 1999) which inappropriateness in terms of relationship mapping among variables is now being discovered. Secondly recent researches claim ANN models are better alternatives to MLR (Alquahtani and Whyte, 2013; Bode, 2000; Brass et al., 1994; Graves and Schmidhuber, 2009; Ogunlana et al., 2000).

3.8 The research concept

Miles and Huberman (1994) defined a conceptual framework as a visual or written product, explains either graphically or in narrative form, the main thing(s) to be studied, the key factors, concepts, or variables and the presumed relationships among them. A conceptual framework is also the system of concepts, assumptions, expectations, beliefs, and theories that support and inform a study which forms a key part of the research design (Robson, 2011; Maxwell, 2012). Conceptual frameworks are therefore abstract representations, connected to the research's goals that direct the collection and analysis of data. Shields and Rangarajan (2013) argue that it is a tie to purpose, defining a conceptual framework as the way ideas are organized to achieve a research project's purpose or aim. Conceptual frameworks are important organizing devices in empirical research. Shields (1998), Shields and Tajalli (2006), Shields and Rangarajan (2013) identified several types of conceptual frameworks, (i) working hypothesis-exploration or exploratory research (ii) descriptive categories or descriptive research (iii) practical idea type (iv) models of operations research-decision making and (v) formal hypothesis-explanation and prediction.

In the context of empirical research, a conceptual framework represents the researcher's synthesis of literature on how to explain a phenomenon. It maps out the actions required during the study, given previous knowledge of other researchers' point of view and the observations about the research (Regoniel, 2015). The conceptual framework, therefore, steers the whole research activity and serves as a map or rudder that guides towards realizing the objectives or intent of the study (McGaghie et al., 2001). A conceptual framework is primarily a conception or model of what is planned for study, and of what is going on and why a tentative theory of the phenomena that is being investigated. The function of the concept of this research is to inform the rest of the design, help in the assessment, refinement of goals, the research questions, select appropriate methods and identify potential validity threats to conclusions that would be drawn.



KEY	
BC	Significant cost factor
BT	Significant time factor

Figure 3.2: The conceptual back-propagation ANN models for construction project cost and time overruns assessments/predictions

Artificial Neural Network (ANN) for construction project impacts prediction models are proposed based on adaptability to construction project cost and time performance challenges. This research is of the view that data on the construction project initial contract sums and final account as well as the estimated and final construction durations are trainable for relationship pattern learning. Moreover, such learnt patterns are useful for the design of construction cost and time impact prediction models, the object of this research. Like Oyewobi (2014) who used a connected construct relationships system and hypotheses to explain the research conceptual framework and Odediran's (2016) graphic explanations of the conceptual model, the study's conceptual frame is illustrated with network of ANN interconnected models. The impact prediction models are illustrated with Figures 3.2 for construction cost and time respectively. When fed with field data at the input layer will automatically generate the needed impacts at the output ends. Back-propagation (BP) algorithm is used, it belongs to the realm of supervised learning known for theoretical soundness (Rumelhart et al., 1986), good performances in modelling nonlinear functions, and coding simplicity. Back-propagation (BP) algorithm is the most widely used training technique relatively to unsupervised and reinforcement learning for problems like this study (Al-Tabtabai et al., 1999; Hegazy and Ayed, 1998; Setyawati et al., 2002; Squiera, 1999). In the learning process, the input values which are the significant cost and duration driving factors identified using the Pareto rule discussed in the methodology Chapter are imputed (forward-propagated) into the input layer. Output values which are the overruns or impacts are given in the output layer (last later).

Errors are computed from the differences between the known actual outputs and those of the network. These errors are used by the programme to calculate the adjustments to the weights in the last layer. The adjusted weights reduce the output error. The programme can also roughly estimate error values from the previous layer of the network. Using these values, the weights of the last layer of the connections in the network are adjusted to reduce significantly such errors. This process of backpropagation (Amusan, 2011; Chen and Hartman, 2000; Kaur, 2016; Noriega, 2005; Odeyinka, 2003; Odeyinka et al., 2012; Zhang and Fuh, 1998) can be repeated for all layers in the network, from the last back to the first. As the training cycle of forward-propagation followed by back-propagation is repeated over and over (Datt, 2012), thus the output error is reduced.

Although the concept comprises of complex internal operations which scholars call black box, a bit of the internal mathematical operations has been described in sections 4.6 of the methodology Chapter. The following Equations 3.1, 3.2, 3.3, 3.4 and 3.5 summarize the black box nature of artificial neural network. A BP neuron transfers its value as shown in Equation 3.1. Output node = $\alpha\ [\sum wij \times j(t) - \beta j]$.. Equation 3.1.
Where α is the sigmoid function, w_{ij} is the strength of the connection (weight) from node i to node j, x_j is the output value from node i, and βj is the threshold value. When a neuron is activated, the new output is equal to the sigmoid function of the sum of the products of the weights and the activities of the input connections minus the threshold of the node. The sigmoid function is defined by Equation 3.2

$$\alpha = \frac{1}{1+e^{-s}}$$ ....Equation 3.2

Where s is the weighted sum of the inputs and e is the base of the logarithms. The patterns' error is measured using a performance measurement called mean square error (MSE) or root mean square (RMS). The mean square error is a good overall measure of whether a training run was successful (Albino and Garavelli, 1998; Al-Tabtabai et al., 1999; Al-Tabtabai and Alex, 2000) as Equation 3.3. In line with Gunaydin and Dogan (2004), it was used in this research for evaluating the performance of the model during the training process.

RMS/MSE = $\frac{\sqrt{\sum_{i=1}^{n}(t_i - o_i)^2}}{n}$..Equation 3.3

MAPE = |MSE%|………………………………………….. Equation 3.4

Where t_i is the actual output and o_i is the predicted output produced by the network. The main objective is to minimize this function, i.e. to change the weights of the system in proportion to the derivative of the error with respect to the weights. The relative mean absolute deviation (Rel.MAD) between the actual and the predicted output which need not be too large, is computed manually using Equation 3.4, while the range between the maximum and minimum need not to be too wide for good predictive model strength (Odeyinka, 2003).

Rel.MAD = $\frac{1}{n}\sum\left(\frac{t_i - o_i}{t_i}\right)$..Equation 3.5

3.9 Summary of the research conceptual framework

Four issues of construction cost and time performance yet to be addressed in researches were summarized on a heading titled theory of cost and time overruns. One of such issues is the relationship between construction project complexities and overruns. The term complexity in terms of construction projects was therefore reviewed from existing literature vis-a-vice the interrationship between project attributes, the interface and consequential impact on cost and time performance. Dimensions of construction project complexities were discussed with examples of complex and less complex projects, using project construction cost and completion time parameters. Salient basis of complexity classification yet to gain popularity in construction project researches were highlighted as well as current absence of standard universal basis for construction project complexity classifications especially for uncomplicated or less complex projects. Research hypotheses emerged from an aggregation of the gaps in construction project complexity classification, review of the dual influence of some cost and time driving factors, the stochastic relationship between cost and time impacts and influence of the driving factors as well as the differentials between cost and time performance in complex, uncomplicated and moderaretely complex projects. Other basis upon which the hypotheses are founded include differences in levels of construction project complexity. Because of the high predictional precisions of ANN models over the orthodox MLR predicton technique, ANN cost and time network prediction models were conceptualized for this study with an illustration of the operational modalities. Methodologies suited for data collection and analysis are discussed in the next Chapter – research methodology.

CHAPTER FOUR: RESEARCH METHODOLOGY

4.1 Introduction

This chapter discusses the need for research philosophy in conducting research; it illustrates how philosophical choice guides every living being and articulates the underlying philosophical assumptions of this study. It also presents the research approach, describes the study area and the justification of the researcher's choice of that area. It describes the population of the study, the design of the data collection instrument, the criteria for judging the quality of the questionnaire, and the gains from pilot testing this research data collection instrument. Also discussed are the research, population, and sample size, the determination, sampling techniques, how the questionnaire were administered and collation of the returned questionnaire. An explanation is provided about the research unit of analysis, and the methods used in analyzing the collected data. The ethical principles considered in conducting this research, are also explained.

4.2 Research philosophy

A philosophy is a comprehensive system of ideas about human nature and the nature of the reality that man lives in. Philosophy is a guide for living, because the issues it addresses are basic and pervasive, determining the course taken in life and how neighbours treat each other. Addressing research philosophy involves being aware and formulating beliefs and assumptions. Each stage of the research process is based on assumptions about the sources and the nature of knowledge. In summary, research philosophy is like a roadmap for research, without which one's investigation lacks illuminated direction (Sefotho, 2015). Given the foregoing, it then follows that the most widespread systems of ideas that offer philosophical guidance should be religion. Religious beliefs can guide if the believer believes without any form of self-deceit, but that is enough for a man of the world. Total philosophical guides are in a personality, his children not being slaves to rigid principles and doctrines but master over all other manners of philosophical prescriptions.

Out of the four major research philosophies; pragmatism, interpretivism, realism and objectivism (See Figure 4.1), the latter, which is objectivism, is usually the philosophy of rational individualism founded by Ayn Rand (1905-1982). Regarding a woman's preference for a man, Rand dramatized in two novels that her ideal man is such a producer who lives by self-effort and does not give or receive the undeserved, who honors achievement and rejects envy (Rand, 1967a). A woman's philosophy of man, for Rand is the concept of man as a heroic being, who takes self happiness as the moral purpose of life, productive achievement as noblest activity, and reason as the only absolute (Rand, 1967). One cannot achieve happiness by wish or whim; fundamentally, the philosophy requires rational respect for the facts of reality, including the facts about human nature and needs. Spiritually, happiness requires that one lives by objective principles, including moral integrity and respect for the rights of others. Politically, objectivists advocate laissez-faire capitalism. Under capitalism, a strictly limited government protects each person's rights to life, liberty, and property and forbids that anyone should initiate force against anyone.

The heroes of objectivism are achievers who build businesses, invent technologies, and create art and ideas, depending on their own talents and on trade with other independent people to reach their goals. Objectivism is optimistic, holding that the universe is open to human achievement and happiness and that each person has within them the ability to live a rich, fulfilling, independent life. These are idealistic ideas which seem to undermine the source or power behind such powers of success. The profounder of objectivism seems to forget that no one had the choice of parentage, issues regarding success and greatness are what they should, and therefore, no matter the level of objectivism, the philosophy eventually diffuses into realism. The following Section 4.3 illustrates the objectives of this research within the frame of research philosophy discussed.

4.3 Underlying philosophy of the study

Research philosophy reflects the researcher's important assumptions which serve as the basis for the research strategy. The layers in Figure 4.1 (not the shape) like the strata in an onion illustrate the identification of philosophical assumptions in a research. The philosophical positions like positivism, realism, interpretivism and pragmatism are positioned at the outer layer, showing their importance as the first topic to be clarified in a research methodology. In them the researcher answers the question of; what is the philosophical base of a research (which of the four research philosophies in the outer layer of the research onion is this study?

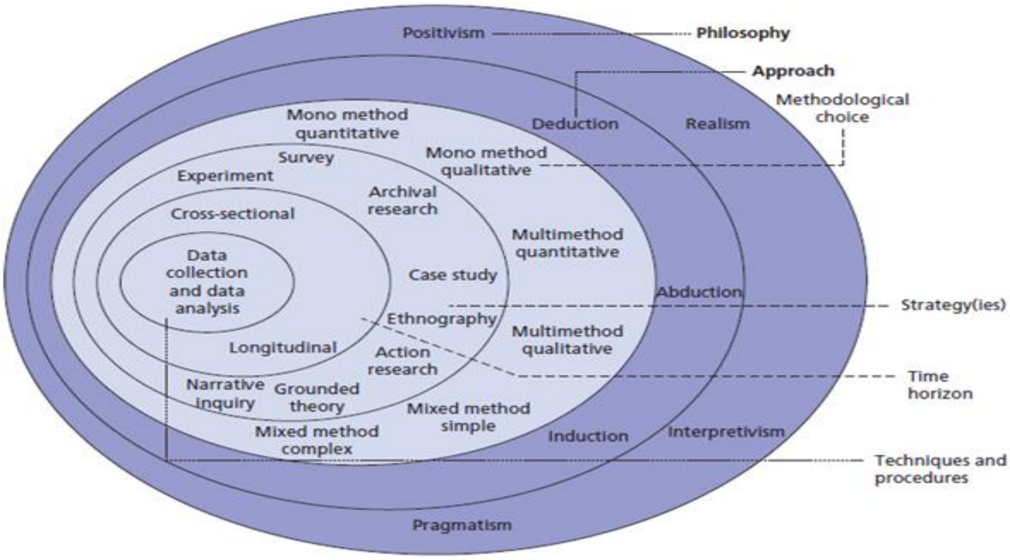


Figure 4.1: Research philosophy in the research onion (Adopted from Saunders et al., 2012: 108**)**

Research philosophy addresses the beliefs, values and principles underlying a detailed study. The word philosophy derived from the world of Greek is the love of wisdom (Akogun, 2000; Sample, 2010), it deals with the source, nature and developmental process of knowledge. Saunders et al. (2012) defined and explained research philosophy as the development of the research background, research knowledge and its nature or the belief in the ways in which data about a phenomenon are collected, analyzed and used. Research philosophy is also defined with the help of research paradigm which is the broad framework, comprising perception, beliefs and understanding of several theories and practices that are used to conduct a research (Cohen et al., 2007). It can also be characterized as a precise procedure, which involves various steps through which a researcher creates a relationship between the research objectives and questions. According to Gliner and Morgan (2000) paradigm is a way of thinking about a research and the conduction. It is not strictly a methodology, but more of a philosophy that guides how the research is to be conducted. Research paradigm and philosophy comprises various factors such as individual's mental model, way of seeing things, different perceptions and variety of beliefs towards reality. The concept influences the beliefs and value of the researchers in providing valid arguments and terminology to give reliable research results. There are important philosophical differences between studies. The choice between two research philosophies has traditionally represented a major point of debate among academics. In research, the philosophy of a study is specified, together with the reasons behind it. The choice of positivism-objectivism philosophy in this study is impacted by practical implications of the envisaged research results.

The research topic, aim, objectives and questionnaire items of this study are centred on building construction project cost and time performance assessments. Basically, the research methodology hinges on the availability of data that are important in answering the questions posed. Important philosophical questions that emerged were; What if such data are inexistent? What if the research was centred on an area where there is a language barrier between the respondent and the researcher? Will the study be discontinued? Objectivists by their nature have practical answers to difficult philosophical questions. In this research the direct information sourcing from project participants became a viable alternative to the problem of dearth of construction management database in the study area.

Given the aim of this research from the main question which is broken into sub-questions in Chapter 1 section 1.4, they align with the positivism and objectivism-realism philosophy. By the framing the researcher is asking for unknown and unhidden facts that can be revealed through an organized system of investigation. That assumption of latent information lying with the research respondent, cuts across the framing of the entire research instrument. That guiding trend of this inquiry is capable of supplying data that is not easily manipulated. The underlying assumption is; carefully sourced primary and secondary data if analyzed, the findings can provide information that will advance the knowledge horizon (paradigm shift) in the management of construction projects. This study's questionnaire items can be then classified into the perspective of positive ontological inquiry that are independent of the participants' and researcher's influence. For example, the first section of the questionnaire asks for unidentified but prevailing construction management statistics which are not subject to a researcher's subjective influence. The main divisions of relevant assumptions in this research; epistemology (knowing), ontology (being) and axiology/methodology (acting) (Heron and Reason, 1997; Blaikie, 2010) are discussed in the following sections.

4.3.1 Ontology

Ontological research philosophy identification in a research process is of critical importance (Neuman, 1997) as it determines the choice of the research design. Ontology, the speaking of being, is the philosophical discipline that asks, what is? And what does it mean to be (Newman and Benz, 1998)? Ontology (theory of being/reality/essence) branches into objectivism and subjectivism (constructivism or interpretivism). It researches the fundamental questions of being, and thus, in everyday parlance, one could say that it studies the nature of reality. Ontological assumptions form one of the most important building blocks of paradigm and they are so fundamental that they are rarely questioned. One needs to know what is or what exists prior to researching it. Objectivism is an ontological position that asserts that social phenomena and their meanings have existence that are independent of social actors (Bryman, 2012; Rand, 1975).

This study is philosophically inclined towards positivism-objectivism. In other words, construction project cost and time performances are manifesting due to what should have been done that are presently not being done properly or that certain factors intercept the construction processes causing variability between the planned and the achieved project objectives. The research adopts a positivist paradigm and objective view of reality because it deals with cost and time which are objective in nature and can be counted. This was also the ontology used in similar researches by (Knight and Ruddock, 2008; Richard, 2010; Pham, 2018).

4.3.2 Epistemology

Epistemological dimensions of research address issues regarding presentation. Epistemology (the theory of knowledge) branches into positivism, interpretivism, pragmatism and realism. Some studies are in positivist (objectivism) epistemology, where no subjective truth is accepted and truth or meaning generation comes through social engagement with the world (Burns et al.., 2018; Singh and Walwyn, 2017). Positivism-realism presumes that the researcher and the research problem are separate and are independent entities that do not influence one another. There is a search for the facts in objective and quantifiable terms, a search which holds empirical data in the highest esteem. In community-based research, the researcher participates in the known and that evidence is generated in at least four interdependent ways – experiential, presentational, propositional and practical (Heron, 1996; Heron and Reason, 1997). Positivism-objectivism forms the basis of this study’s research design, which is shown in the hypotheses conjectured and the design of the data collection instrument (Appendix IV). Epistemologically, this research is inclined towards objectivism and ontology. To continue the inquiry, an alternative to the needed corporate archival data was created by sourcing information from records of participants on the construction projects (Abam et al., 2017). In the methodological approach, concepts were operationalized for measurement (Dilts and Delozier, 2000; Easterby-Smith et al., 1991). As shown in Table 4.1, the study adopted a survey method and used large samples of highly structured questionnaires generally associated with the positivist philosophy (Saunders et al., 2012) in the collection of quantitative data. Moreover, facts were focused on, causality and fundamental laws were searched, phenomena were reduced to simple elements, and hypotheses formulated from the research questions were tested for confirmation (Gliner and Morgan, 2000; Olaseni et al., 2013) as in Ulum (2016).

Table 4.1: Research philosophies and associated data collection methods

	Pragmatism	Positivism	Realism	Interpretivism
Popular data collection method	Mixed or multiple method designs, quantitative and qualitative	Highly structured, large samples, measurement; quantitative, but can use qualitative methods	Methods chosen must fit the subject matter, quantitative or qualitative	Small samples, in-depth investigations, qualitative

Source: Adapted from Saunders et al. (2012: 119)

The implications of the research philosophy on the research strategy in general and the choice of primary data collection methods is an important part of research report.

4.3.3 Axiology

The axiological or methodology perspective of a research paradigm is aimed at depicting the level of consistency, reliability or otherwise reconstructing or extending the previously held theories or construction. Axiology urges congruence between ontological and epistemological assumptions (Gericke, 2012). It plays an important role in setting the standards and requirements of an acceptable research approach and research techniques. Making the axiology explicit helps to set and clarify the guiding tone and rigour for action in research. Axiology is a branch of philosophy that studies judgments about value; it is the research topic or processes of social enquiry that are concerned. The role that the research values play in the stages of the process is of great importance if the research results are to be credible (Heron, 1996).

In relation to the topic under study, the researcher places great importance in (i) treating construction cost and time performances in a single study rather than in eparate studies, since some intervening factors influence both. According to Adu and Ekung, 2017 failure in any of the project criteria of cost, time and quality affects the others. Schedule delay results in a cost overrun factor (Dlakwa and Culpin, 1990; Enshassi et al., 2009; Omoregie and Radford, 2006 and Shen, 1997). Baloyi and Bekker (2011), Rahshid et al. (2013), Sambasivan and Soon (2007) argue that overrun factors do not stand alone, the ultimate cost overrun results in multiple factors which contribute to the final construction cost differential. Items omitted from the estimates due to design errors or inadequate scope frequently result in change orders which increase construction cost as well as time of delivery (Shrestha et al., 2013). Money and time are inextricably linked, and the consequences are considerable when durations are longer (Frizelle, 1993).

Analysis in section 2.5.3 shows that the percentage of these dual factors lies between 53% and 60% of the total number of either cost or time factors. The foregoing links between money and time and the considerable consequences when construction programmes are longer, justify the combined studies of construction project cost-and-time challenges. Though many studies are based on the professional training of quantity surveyors, building and civil engineering and focus on either cost or time, some however, combined the two factors in one study. Such combined cost-and-time researches (Agyakwah-Baah, 2010; Al-Momani, 2000;

Fugar and Agyakwah-Baah, 2010; Haseeb et al., 2011; Jeykanthan and Jayawardena, 2012; Pathiranage and Halwatura, 2010; Sambasivan and Soon, 2007) were not aiming to find a nexus between the two driving factors. This study takes advantage of the linkage between construction project cost and time, in the design of cost and time impact prediction models that invariably yields a twin impact assessment tool that previous missed by; (i) sourcing field data from the same project and use in the design of cost-and-time impact prediction models, which yields a twin impact assessment tool; (ii) data were collected by allowing the respondent to do the supply freely. That value consideration expressed in this study's survey reduced respondents' attempts to exaggerate or try to impress the research worker who sat nearby, (iii) respondents were given privacy to delve into files to recall quantitative data pertaining to cost and duration of completed construction projects, free from casual remembrance of past events. These methodological styles are valued more highly than personal interactions with respondents through interviews and telephone calls. Such quantitative data which depicts the paradigm adopted in this research, were sourced with questionnaire items in sections 2, 3 and 4 of the data collection instrument (see Appendix IV).

4.4 Research approaches and strategies

Johnson and Clark (2006) emphasise that the researcher needs to be aware of the already committed philosophical assumptions expressed in the adopted research strategy because it has significant impact on the research and on the understanding of the research stages. Research strategy or design is the plan, structure and strategy of investigation concerned with how to obtain an answer to research questions and to control variance (Ofo, 1994). Two main research approaches are qualitative and quantitative. Qualitative research is characterized by its aims, which relate to understanding some aspects of social life, and its methods which (in general) generate words, rather than numbers as data for analysis (Brikci, 2007). The qualitative research method aims to answer questions about the 'what', 'how' or 'why' of a phenomenon rather than 'how many' or 'how much', which are answered by a quantitative method of enquiry (Rasinger, 2013).

In qualitative evaluations, contexts, solutions, events, conditions and interactions cannot be replicated to any extent, nor can generalizations be made with confidence to a wider context than that studied. Basically, the richness, individuality and subjective nature of a participant\s perspective and understanding is not amenable to the usual criteria of conventional standard of reliability and validity. However, these do not make such understanding any less real or valid for that participant and their explanatory function for a person's behaviour is highly predictive. Time required for data collection, analysis and interpretation is considerable in the holistic examination and aggregate interactions, reactions and activities of the subjects. Toy (2012) notes that because of the intimacy of participant-observer relationships within the setting, there is no doubt that the researcher's mere presence has a profound effect on participants in the study. The associated promise of anonymity makes the qualitative evaluator's task particularly difficult in terms of preparation and presentation of results. Issues of bias are therefore numerous in qualitative researches, David and Mahoney (1996) further observed that the variable of time is more of a barrier especially where attempts are made to replicate accumulated findings of over three years. A comparable length of time would again be necessary for adequate observation of a similar group (Flick, 2011; Sallee and Flood, 2012). Similarly, there is no guarantee that the replication could be of an identical social context. The most feasible achievement is a high degree of similarity and a recognition of impossibility of absolute reproduction.

4.4.1 Meaning and developmental history of quantitative research

Quantitative analysis is the scientific approach to managerial decision making, devoid of emotions and guesses. The approach begins with data which in factory settings are raw materials (Render et al., 1985). The heart of quantitative analysis is the data manipulations and processing into valuable information to individuals, communities, national and international benefits in decision making. Quantitative analysis has been in existence from genesis, but it was Frederick W. Taylor (1856-1915) who in the 1900s pioneered the principles of a scientific approach to management. During the Second World War, many new scientific and quantitative techniques were developed to assist the military. The new techniques, according to Render et al. (ibid) were so successful that after the war many companies started using similar techniques in managerial decision making and planning. This has manifested in many companies employing staff of operations research or managerial science personnel or consultants to apply the principles of scientific management to challenges and opportunities. Till date quantitative researchers as Cardoso (2014), Reginald and Jeanette (2012) are emphasizing on scientific management in everyday managerial communication situations and the application of Taylor's scientific management principles in current organizational management practices because of its suitability. In answering this study's main question, the quantitative scientific approach is most suitable because of its focus on exploration of the relationship between impacts and influence of factors (Render et al. 1985).

4.4.2 Aims of quantitative analysis

Quantitative method aims at measuring something (such as the percentage of people, or the number of households). In quantitative research, the aim is to determine the relationship between one thing (an independent variable) and another (a dependent or outcome variable) in a population (Render et al. 1985). Quantitative research designs are either descriptive (subjects usually measured once) or experimental (subjects measured before and after a treatment). A descriptive study establishes only associations between variables. An experiment establishes causality (Creswell, 2013).

The failure of a quantitative technique to assist in solving a problem is often a result of its improper application than a fault of the technique. According to (Render et al. 1985) reasons for failures of past quantitative solutions proffered might have been; failure to define the real problem, underestimating the time required to develop and implement the most appropriate technique or techniques, underestimating the total cost of using quantitative techniques, resistance to change and reluctance of managers and decision makers to trust and act upon results obtained using unfamiliar techniques and overemphasis on theory and underemphasize on application. The authors further, said it is not enough to know how a quantitative technique works; the limitations, assumptions and specific applicability of the technique must be understood. The successful use of quantitative technique usually results in solutions that are timely, accurate, flexible, economical, reliable, and easy to understand and use. Qualitative and quantitative methods may appear to be opposites, derived from different philosophies, yet both are legitimate tools of research and can supplement each other providing alternative insights into human behaviour. One method is neither better nor poorer than the other. The choice of a research approach is based on an informed understanding of its suitability to the research (Akogun, 2000).

4.4.3 Adopted research approach and strategy

The modelling processes and procedures adopted in this research from the data collection through to the development and validation of the models are summarized in the following Figure 4.2.

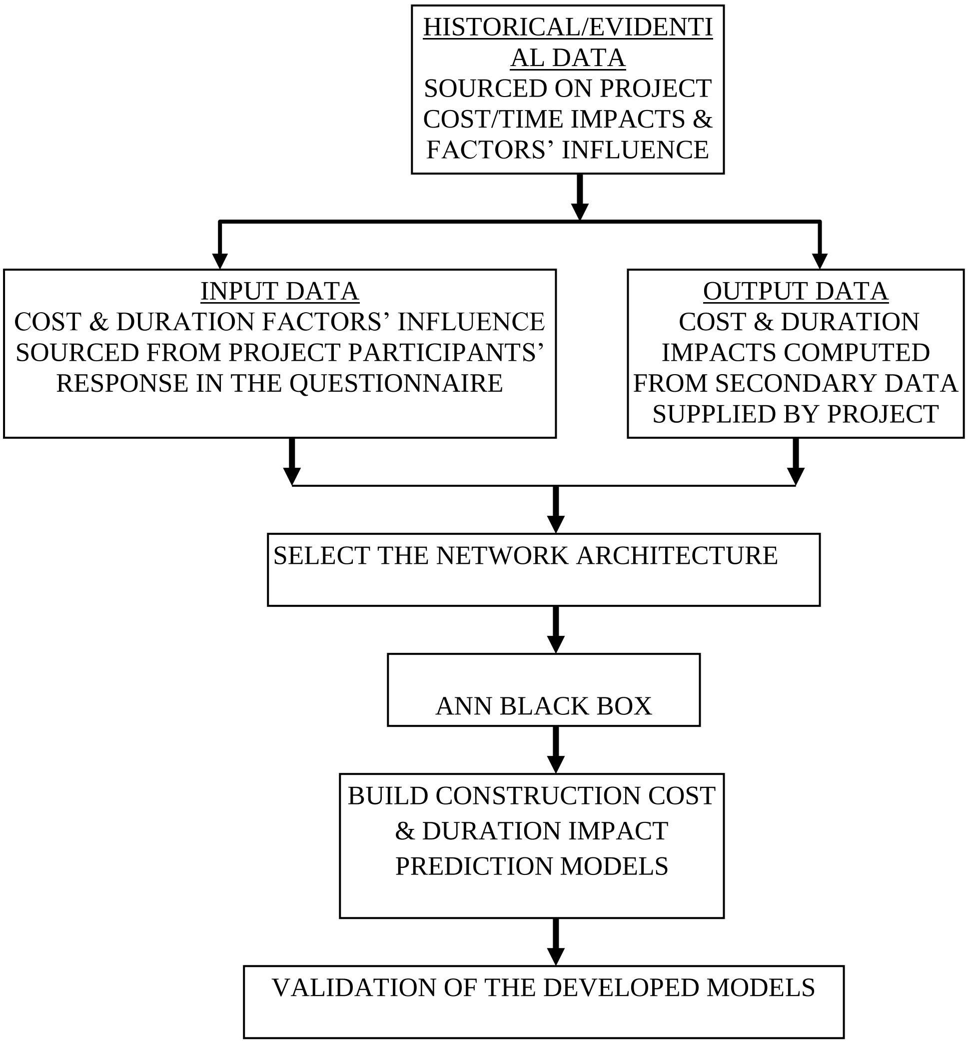


Figure 4.2: The study's construction cost and duration impact prediction modelling processes flow chart

Major aspects of this study involved collecting and converting data into numerical form for statistical calculations to be made and draw inference. This justifies the quantitative approach which is normally associated with the positivist paradigm. Quantitative method adopted in the research helped in the research results interpretations and gave a better understanding of the reality and the implications of quantitative data. The main emphasis of quantitative research as this, is on deductive reasoning which tends to move from the general to the specific [this is sometimes referred to as a top-down approach] (Akogun, 2000). Like Shah (2016) snd Okafor (2016) quantitative research method featured prominently in this study.

4.5 Study area

Nigeria was structured into six geopolitical zones in the year 1995. The zones consist of states with similar cultures, historical background and close territories (Gboyega, 1995). The study area (North-east geopolitical zone) is situated at the top right hand in the nation's map consist of six states; Adamawa, Bauchi, Borno, Gombe, Taraba and Yobe states. The zone bounded on the right by Cameroon republic, at the top by Niger and Chad republics. On the left-hand side and in the south is the North-central geopolitical zone.

Jolaoso et al., (2012) in appraisal of the maintenance of public residential estates in Ogun state reported on National Housing Policy of 1991. In that report, the three arms of government charged the housing corporations and related organs with (i) the responsibilities of facilitating the design and construction of new housing units for low income groups (ii) improving upon the existing housing conditions (iii) reducing the production cost of housing units (iv) encouraging the manufacture and use of local materials (v) providing scientifically-based physical plan to support habitable environment. In compliance, construction activities therefore have been spreading from state capitals to local councils including those of the study area. The administrative headquarters of each of the six states are Yola, Bauchi, Maiduguri, Gombe, Jalingo and Damaturu due to their relatively larger volumes of construction work than the other towns attracted more work force. The location of states' administrative headquarters' ministries as, educational and health care facilities, military and paramilitary stations and their housing estates, banks, manufacturing industry and airports help in sustaining construction activities and the attendant materials manufacturing, consultancies, sales and services.

The north eastern Nigerian construction industry no doubt would not be excluded from issues of construction projects poor performances that Ameh et al. (2010) attest is global. Okafor (2016) noted the level of project delay and failures in Nigeria. In addition, Amusan et al. (2017) in the South-west geopolitical zone took Nigeria, Cameroon, Ghana and Togo as study centre. Ade-Ojo and Babalola's (2013) took South-western geopolitical zone as study area. Saidu and Shankatu (2017) studied an ongoing project in Abuja. Thirty-two construction project performance studies were conducted across Nigeria between 1998 and 2017. Apart from Amusan et al. (2017) whose study centred on four developing nations combined, Ameh et al. (2010) and Idoro's (2012) study centred on the six geopolitical zones of Nigeria combined. One other study (Bello, 2017) did not name the study area. Four other studies (Diugwu et al. 2017; Idiake et al. 2015; Saidu and Shankatu, 2017; Usman et al., 2014) focused on Abuja (Federal Capital Territory of Nigeria) alone. Only six studies (Bala and Anosike, n.d; Dakars et al., 2004; Gundiri, 1998; Ishaya, 2000; Kunya, 2006; Oraegbune, 2008) were undertaken in the study area in that period.

While the dates of two (Gundiri, 1998; Ishaya, 2000) of the studies are quite old, requiring update the third study (Bala and Anosike, n.d) dealt with factors affecting construction cost of housing projects and not factors influencing construction cost generally, the focus of this study. There is therefore a dearth of current research in the field of construction management in the study area. Moreover, the study area has been facing insecurity and insurgencies (Amalu, 2015) for the past fifteen years. This may have had additional negative economic impacts (Gbahabo and Ajuwon, 2017; Mbasau et al., 2016) and industrial impacts on construction project cost and time performance. The negative impacts on construction projects include developmental hindrance, which can further be compounded by high levels of insecurity, crime (Adekola and Enyiche, 2017; Baiyewu, 2012; Ewetan and Urhie, 2014) and insurgencies like those in- north eastern Nigeria, where construction operations are frequently but unpredictably violently disrupted (Aworlu, 2015).

Violent conflict can have a wider economic cost across geographic spaces (Ikpe, (2017) and to other spheres of government's responsibility towards its citizenry. For example, Adebayo (2013) analyzed Nigeria' 2013 budget. In the budget a total of ₦1202bn naira was earmarked for critical infrastructure comprising power, works, transport, aviation, gas pipelines, federal capital territory, health and education, while ₦953bn naira was earmarked for national security, comprising mainly the armed forces and police. The analysis indicated that in a single fiscal year funds allocated to security alone were almost equal to funds allocated to education, health and critical infrastructure combined. The analysis reveals the extent to which governments' efforts can be diverted from buildings and infrastructural development in periods of insecurity and insurgency.

Violence by the Boko Haram sect was first witnessed in Nigeria between years 2001 and 2004 when it launched attacks against police stations and other public buildings (Pham, 2012). The sect, a controversial Nigerian Islamic militant group, seeks the imposition of Shariah law in the northern states. The official name of the group is Jama'atu Ahlis Sunna Lidda'awati Wal-Jihad which in Arabic means People Committed to the Propagation of the teachings of the Prophet and Jihad (Eguavoen, 2015). It was dubbed Boko Haram by the residents of Maiduguri where it was formed in 2002. Translated from the Hausa language into English, it means Western education is forbidden. The name was given because of strong opposition to Western education which is seen as an instrument of corruption of the Muslims (Othman et al. 2015). In 2009 to 2011 the group which was confirmed to have external links with other insurgency groups around the world (Eguavoen, 2015), increased its terrorist activities within the state of Nigeria, manifesting in various forms.

In Bauchi, Kano, Yobe and Borno States, public institutions as army barracks, motor parks, shopping malls, market places, business areas, banks, immigration offices, prisons, churches and schools were attacked with bombs. The sect abducts and kills people, make business including construction site operations hold up or stop their activity entirely (Amalu, 2015; Oshio, 2009; Othman et al. 2015; Reuters, 2013). The incessant insurgency activities of the sect caused many members of the public in the affected states to flee from the area (the study area) (Adejimola and Tayo-Olajubutu, 2009). These included carpenters, bricklayers, plumbers, fitters, plant and mechanical equipment operators, truck drivers, painters, electricians, general labourers and food vendors. No farming activities took place for years in Borno and Yobe states, the worst hit states. It affected the inflow of foreign investors, an example is Julius Berger, the construction giant, which pulled out of the north-east because of the insecurity situation (Eseoghene and Efanodor, 2016). As at August 2013 over 882 classrooms in Borno State were damaged and from June to September 2013 all schools were closed in Yobe State (Awortu, 2015). Human activity stood still in Mubi, as the people fled. Most banks in Mubi metropolis were yet to be rebuilt at the time of the study (2017). Not all the 200 girls who were taken hostage in the Government Secondary School in Chibok April 14, 2014 in Borno State (Hassan, 2014) returned.

Insecurity and insurgency thus have a negative relationship with business prosperity (Gbanite, 2001; Nwagboso, 2012) and by extension the smooth and continuous flow of planned construction operations at sites. Based on the foregoing, research into north eastern Nigeria construction projects cost-and-time performance has become imperative. The current study focused on public projects, because governments are the largest clients in the building and infrastructure construction markets (Ade-Ojo and Babalola, 2013; Olatunji, 2008a, b).

4.6 Design of data collection instrument

Though the study's population units are completed public buildings, for which archival data of cost and construction durations should be most suitable, there were limitations and problems of availability and lack of databases in the study area. The alternative was sourcing the data directly from construction professionals who had participated in such projects. These were architects, builders, civil/structural/services engineers, quantity surveyors, site supervisors and general foremen. A questionnaire survey was therefore adapted to first find data about the interplay of construction cost and time drivers, as witnessed on an identified project, per respondent, during execution stage. The second step was to find data on project costs, and on time schedules from inception to completion. The questionnaire items were developed to supply the data which, under analysis, would address the main research question.

The data needed for analysis to answer the research questions, test hypotheses and achieve the research aim and objectives were the evidence of the interplay of factors on the projects' initial contract sums and estimated construction durations. Numerical data on project initial contract sums, final costs, and estimated and actual construction duration of completed buildings were required for the computation of cost-and-time deviations. Construction cost (43) and time (49) drivers' influence factors, identified from the literature search in Chapter Two, were used in the design of the survey questionnaire.

The questionnaire was divided into four sections. The first section to find out the background details of the participants and the second on the project details comprising construction cost and schedule. Respondents were asked to identify a project they had worked on between year 2012 and 2017. In the third and fourth sections of the questionnaire, the participants were asked to rate their opinion on the influence of the 43 costs and 49 time driving factors on a six-point Likert scale which ranges from 0 to 5-points. None, very low, low, moderate, high and very high were represented by 0, 1, 2, 3, 4 and 5 respectively. Using the method of assessment of the influence of cost and time factors discussed in section 2. 7, respondents were asked to tick a score on the scale to indicate the level of their experience of the factors on the identified project (see Appendix IV). For example, a respondent whose experience of the influence of fluctuation/inflation on project cost was low, ticked 2, while someone experiencing a very high influence ticked 5.

The questionnaire reviewers were experts in the field of construction management. The results of their review indicated that some items in the questionnaire had the same meaning and should be merged, and others were unnecessary and should be deleted. Their feedback was used in revising the questionnaire prior to distribution. The respondents' ranking of cost and time influencing factors were based on the occurrences of the factors on projects on which they participated. Subjective responses were reduced in this study with the use of site records by respondents to supply data and recall the factors that impact on construction project performance. Also, the same question was administered on all respondents, the quantitative nature of the research normalized the subjectivity of their responses. Moreover, potential biases of information supplied by respondents based on their professional differences were reduced in the design of the questionnaire items which was salient on the professions of the respondents.

4.6.1 Constructs used in the questionnaire design

Constructs, characteristics or research attributes to be measured (Messick, 1995) are mental abstractions used in expressing the ideas**,** people**,** organizations**,** events and objects or things of interest. Constructs are therefore ways of bringing theory down to earth, helping to explain the different components of theories, as well as measures of behaviour being observed. In the context of survey research a construct is the abstract idea, underlying theme or subject matter that one wishes to measure using survey questions. Some constructs are relatively simple and can be measured using only one or a few questions, while others are more complex, subtle or require indirect measurements (Aledare, 2013) or a whole battery of questions to fully operationalize the construct to suit the end user's needs. Complex constructs contain multiple dimensions of facets that are bound together by some commonality that compose the construct. Without clearly conceptualizing the construct's dimensions and the common theme binding the dimensions together, the survey developer runs the risk of creating a set of questions that does not measure the intended attribute (Lavrakes, 2008). Conceptual clarity is vital for the communication of research reports. In management studies, the attributes are sometimes difficult to measure directly, hence the indirect assessments using several manifest variables.

Direct measurements of the characteristics and attributes (constructs derived from the influence factors which impact on the bills of quantities contract sum and on the construction operations programme) were difficult. The construction stage cost and time influence factors were operationalized with simple constructs easy for respondents' understanding on the survey instrument. Differences between the initial and actual outcomes of construction project costs and durations were measured on ratio scale (Naira and Week) (Crossman, 2017).

Emsley et al. (2002) and Kim et al. (2004) observed that researchers normally develop cost models for forecasting the total cost of the building based on known characteristics of buildings. Such building characteristics include floor area, foundation type, reinforced framed or solid block wall, type and quality of engineering services, types of roof structure and claddings. The cost models so derived established the basic construction cost at pre-contract stage, which are detailed the in bills of quantities. The constructs used in this study are departures from the building charateristics. This study applies the essence of construction cost-and-time models to real life situations where material prices and labour wages are sensitive to local, political, social-security, environmental and economic dictates, which invariably alter the initial contract agreement. Similarly, in a real-life situation there are inevitable changes in work scope and weather conditions which intercept the smooth flow of site activities, to bring about delays. The focus of the current study is on mechanisms for assessing the needed cost-and-time diffentials between the bill of quantities and final cost across the life of the project. However, such building characteristics used in determining the cost figures in the bills of quantities are subsumed in the 43 cost variables and 49-time variables investigated in this research.

The 43 construction project cost constructs used in this research are fluctuations/inflation of prices, inaccurate cost estimates, contractors' poor cost/financial management, poor cost control systems, lack of relevant information and details, non-adherence to contract conditions, discrepancy/deficiency in contract documents, shortage of materials, government's changes in policy and fiscal measures, delay in equipment supply, low quality materials, external parties' influence, unstable foreign exchange, changes in material specification, weak regulation and control, economic insecurity, unstable and high interest rate. Studies that attest to the factors’ driving influence at the construction stage include, Ade-Ojo and Babalola (2013), Aibinu and Odeyinka (2006), Akanni et al. (2015), Babalola et al. (2015), Gebrehiwet and Luo (2017), Haslinda et al. (2018), Kadiri and Shittu (2015), Kim et al. (2004), Marzouk and El-Rasas (2014), Mbachu and Cross (2015), Morakinyo et al. (2015), Olukyode et al. (2015), Omoregie and Radford (2006), Shrestha et al. (2013).

The 49 construction time constructs used in this research were derived from the following studies: Ameh et al. (2010), Amusan et al. (2017), Asmah (2014), Emsley et al. (2002), Fugar and Agyakwah-Baah (2010), Gana and Olorunfemi (2015), Memon et al. (2010), Odeyinka et al. (2012), Ojo and Dada (2005), Oseghale and Olugbenga (2008), Owolabi et al. (2014), Sunjka and Jacob (2013), Ubani et al. (2015). They are, site accident, incomplete technical documentation, bureaucracy in client’s organization, client’s slowness in decision making, client’s undue interference, delay in drawing preparations and approval, poor site management and supervision, contractor’s inexperience, delay in inspection and testing of completed work, inadequate planning and scheduling, delay in building permit approval, natural disaster such as flood, force majeure, civil commotion/community issues, political instability, insecurity/insurgency, lack of relevant tools and equipment, obsolete/unsuitable construction equipment, poor project management, unclear and inadequate instructions to operators, programme/schedule delay, inclement weather and poor construction programme management.

As stated in sections 2.7 and 4.6, an ordinal scale was used in the ranking of respondents' level of intensity of preferences for the influence of cost-and-time factors witnessed on past construction projects (Crossman, 2017). The rank values ranged bottom-up from 0 to 5, where 0 represents no impact, 1 represents very low, 2 low, 3 moderate, 4 high, and 5 very high in the measurement of influence of the cost-and-time factors that occurred in the construction processes. The data sieved from research participants' completed surveys were carried forward for analysis in the data analysis chapter of this report.

4.6.2 Validity and other criteria for judging the quality of questionnaire designs

Standards for questionnaire quality designs, whether to gather quantitative or qualitative data, emphasize traits of objectivity, validity, reliability, rigour, open-mindedness, honesty and thorough reporting (Ragin et al., 2003; Shavelson and Towne, 2002; Wooding and Grant, 2003; Yin, 2009).

Validity is concerned with the nature, meanings and reality of variables, unlike reliability; it is more than a technique (Akinbile, 2013). A valid research instrument, according to Creswell (2005) is one in which the individual scores on such an instrument are meaningful, and which allows the researcher to draw stable and reliable conclusions from the sample population studied. A measure can be reliable without being valid, but it cannot be valid without being reliable (Adebakin, 2013). Therefore, the extent to which the concept proposed for measurement is measured by a scale is the scale's validity (Rich, 2011; Sirkin, 1995). The indirect assignment of numerals to objects and events in the behavioural and management sciences according to rules, suggests that the instrument needs certification to possess the qualities expected of it. The validity of the measuring scale reduces the multiplicity of individual perception and understanding of the instrument, it gives room for universality, and reveals the data collection instrument's truthfulness and appropriateness (Akinbile, 2013). There are four types of validity: face and content validity constitute internal validity, while the others, criterion and construct validity, form external validity.

4.6.2.1 Internal validity of the research instrument scales

Face validity is the extent to which the measure is subjectively viewed by experts or knowledgeable individuals as covering the concept. Content (rational, logical or sampling) validity is an assessment of how well the breadth of the construct has been assessed (Creswell, 2005). Internally valid research instrument implies the absence of internal errors. The question usually asked is, are all the elements in the survey covered? Internal validity is not usually assessed quantitatively but rather by a careful check of the measurement against the conceptual definition of the construct by experts (Sullivan, 2011). It is based on the subjective assessment of the experienced experts and therefore, cannot be replicated Akinbile (2013).

4.6.2.2 External validity of the research instrument scales

External validity is the extent to which the results of a study can be generalized from a sample to a population. External validity comprises criterion (concurrent, predictive) and constructs validity. Construct validity forms the basis for any other type of validity, from a scientific point of view construct validity is seen as the whole of validity (Mislevy, 2007). Establishing eternal validity for an instrument follows directly from answering the question *is the research design such that there can be a generalization beyond the subjects under investigation to a wider population?* A major consideration is that a sample should be an accurate representation of a population, because the total population may not be available. An instrument that is externally valid helps obtain population generalizability, or the degree to which a sample represents the population. In this research, the sampling method adopted, and sample size determinants helped in ensuring high external validity. According to Akinbile (2013) Spearman Rho correlation and regression analysis, are good determinants of criterion and construct validity.

External validity on its own is not enough for determining validity, meaning the internal and external validity must be combined to ensure validity and usability of a scale (Akinbile, 2013). Thus, in this research cues were taken from similar scales and constructs of past studies in the questionnaire design, thereafter it was corrected, revised and approved by the researcher's team of experienced supervisors, as well as the incorporation of gains from the pilot survey. In addition, the test result of the survey data collection instrument is presented in Tables 4.2 and 4.3. It can be seen from the tables that the Spearman's rho bivariate correlations ($p < 0.000$) of factors randomly selected from sections 3 (cost construct) and 4 (time construct) of the instrument are highly significant at 0.01 level (2-tailed)

Table 4.2: Spearman's rho Bivariate Correlations of the Cost Construct

Bivariate Factors		**Contract Manager's inexperience**	**Contractors' improper contract knowledge**
Contractor managers' inexperience	Correlation Coefficient	1.000	0.266**
	Sig. (2-tailed)	.	0.000
	N	203	203
Contractors' improper contract knowledge	Correlation Coefficient	0.266**	1.000
	Sig. (2-tailed)	0.000	.
	N	203	203

**. Correlation is significant at the 0.01 level (2-tailed).

Table 4.3: Spearman's rho bivariate correlations of the time construct

Factor		**Incomplete Technical Documentations**	**Bureaucracy in Client's Organization**
Incomplete Technical Documentations	Correlation Coefficient	1.000	0.437**
	Sig. (2-tailed)	.	.000
	N	201	201

Bureaucracy in Client’s Organization	Correlation Coefficient	0.437**	1.000
	Sig. (2-tailed)	.000	.
	N	201	201

**. Correlation is significant at the 0.01 level (2-tailed).

4.6.3 Reliability of the data collection instrument

While reliability is concerned with the consistency (Creswell, 2005) with which a researcher's instrument measures an attribute over time (test-retest reliability) and across situations (internal consistency, split-half reliability) (Feldt and Brennan, 1989). Reliability is one of the issues which determine the acceptability or otherwise of a study, it has a base in the data gathering instrument. The implication is, an unreliable research instrument makes the study unreliable; therefore, assessors and future users do not bother to ask further questions about the research. In other words, reliability is the extent to which a measuring instrument contains the variable error in the unit measured, these errors arise from sources: ranging from the instrument itself, administration of the instrument to fluctuations in respondents' mood (Adebakin, 2013).

The unit of reliability measurement varies from 0 to 1 Cronbach's Alpha (α) (Azrilah, 2010). Cronbach's alpha determines the internal consistency or average correlation of items in a survey instrument to gauge its reliability (Reynaldo and Santos, 1999). A reliability coefficient of 1 indicates an error-free measurement and perfect reliability of tests while 0 imply errors all-through. According to Osborne and Banjanovic (2016), the higher the alpha value the better the internal consistency. High alpha values range from 0.70 to 0.99 (DeVellis, 2003; Fraenkel and Wallen, 1996; Kubiszyn and Borich, 2003; Wong and Cheung, 2005; Yang and Qu, 2008). In social science, the alpha values ranging from 0.60 to 0.70 are acceptable (Ghazali, 2008; Meeampol and Ogunlana, 2006; Wong and Cheung, 2005). Earlier studies in this area by Aiyetan et al. (2012), Apolot et al. (2015), Nandakumar (2008), Shanmugapriya and Subramanian (2013) had Cronbach alpha values in the range of 0.6 to 0.7. An 0.55 coefficient is acceptable for measuring broad construct (Van de Ven and Ferry, 1979). Li and Wang (2007) emphasized the acceptability of values between 0.3 and 0.7. Memon et al.’s (2012b) Cronbach’s Alpha values ranged between 0.747 and 0.892.

IBM SPSS statistics version 21 was used to evaluate this study’s questionnaire reliability measures. The Cronbach Alpha value obtained of the combined cost and time constructs of the research instrument is 0.937, comprising 92 factors depicted in Table 4.4. The research instrument was adjudged reliable and fit for use in data collection (responses gathered using the instrument are consistent across all items measured) based on the minimum evaluated Cronbach's Alpha (α) reliability analysis test result of 0.860 (See Tables 4.4 and 4.5) which is in the range of values of similar researches discussed above.

Table 4.4: Reliability test generally for cost and time constructs

Number of Factors	Questionnaire Section	Cronbach's Alpha Based on Standardized items	Cronbach's Alpha (α)
43	Cost Factors	0.887	0.860
49	Time Factors	0.920	0.912
Total (92)	The two constructs	0.946	0.937

A breakdown of the research's two major constructs of cost and time gave Cronbach's Alpha of 0.860 in Tables 4.5 and 0.912 and 4.6. The measured constructs were further compressed for size management purposes into client and consultant, contractor related as well as general factors as shown in the Tables. Cronbach's Alpha values are a little lower than the recommended for the project, subcontractor and supplier related variables in both constructs, listed in Tables 4.5 and 4.6. Pallant (2010) however, noted that Cronbach alpha coefficient are quite sensitive to the number of items in the scales. With short scales as the case here which are fewer than ten items (two items in each), it is common to find quite low Cronbach values of less than 0.5. Therefore, the variables (project, subcontractor and supplier related) were retained in the study, though they have less than significant Cronbach alpha values.

Table 4.5: Breakdown of cost construct

Number of Factors	Construct Classification	Cronbach's Alpha Based on Standardized items	Cronbach's Alpha (α)
12	Client and Consultant Related	0.642	0.529
12	Contractor Related	0.722	0.696
4	Subcontractor and Supplier Related	0.568	0.567
2	Project	0.235	0.235
6	Macro-Economic & Government Policy		
	General Factors	0.582	0.576
7		0.691	0.689
Total (43)		0.887	0.860

Table 4.6: Breakdown of time construct

Number of Factors	Construct Classification	Cronbach's Alpha Based on Standardized items	Cronbach's Alpha (α)
15	Client and Consultant	0.786	0.755
19	Contractor	0.832	0.821
2	Subcontractor and Supplier	0.320	0.320
2	Project	0.418	0.418
2	Macro-Economic & Political	0.595	0.591
9	General Factors	0.663	0.662
Total (49)		0.920	0.912

4.7 Pilot survey

The discovery of challenges with a research plan and equipment or data collection procedures can be excuse for studies' terminations. Suchexcuses apart from being late are unacceptable (Shuttleworth, 2010) in research. To avoid that, pilot studies are usually conducted to test the feasibility of the research processes and procedures (Shuttleworth, 2010). This involves limited distributions and interviews to verify the effectiveness of data gathering instrument, identification of mistakes and checking research participants' misunderstanding of questionnaire items or ease of answering (Oyewobi, 2014). And, to verify the completeness of the questionnaire in capturing the relevant factors and to identify potential challenges (Hassan et al., 2006; Van-Teijlingen and Hundley, 2001). Shuttleworth (2010) emphasized researchers' clarifications of the research route up to identifying the feasible of the statistical tools and software before full-scale research efforts are committed. Thus, pilot testing of this study's data collection instruments in the quantity surveying office of the Physical Planning Unit of Modibbo Adama University of Technology helped in forestalling premature termination of studies.

The advantages of pilot testing a research instrument manifested in this research. The study's initial focus was public tertiary institution education buildings in north eastern Nigeria. The data collection instrument was redesigned and procedures for reaching participants were refined due to experiences from pilot survey. First, was the merging of the two types of survey instruments; types A.1 and A.2 planned for administering on directors of tertiary educational institutions' physical planning units and type B earmarked for project participants which were to be identified and located through addresses supplied in type A.2 form. The forms were merged into one for ease of administrations. Secondly, the pilot study revealed that Tertiary Education Trust Fund's (TetFund) the major sponsor of capital projects in Nigerian Universities, Polytechnics and Colleges of Education operates a policy that does not entertain cost overrun. That policy and its attendant challenges on the research objectives were unknown until the small-scale rehearsal of the survey was conducted in two public tertiary institutions' physical planning unit in the study area. The study focus was thus revised from a survey of public tertiary educational institution buildings to public institution buildings generally which enabled the survey to progress.

4.8 Population of the study, sample size determination and sampling technique

The following subsections discuss the study population, sample size determination and sampling method used in the study.

4.8.1 Population of the study

Banerjee and Chaudhury (2010) define population as the entire group about which some information is required to be ascertained. This study's population are therefore completed public (government) buildings in the study centre (north eastern Nigeria). Public in the Nigeria context comprises the three tiers of governments; federal government, the six state governments and the local councils together with the agencies. Completed public buildings in the study area spread through the entire geographical zone. Knowledgeable construction participants who are professionals; architects, builders, civil/structural and services engineers, quantity surveyors, site supervisors and general foremen in the context of this research were taken as the research population since they supply data on the research population (completed buildings). The size of such groups of professionals being large and unknown because of the numerical strength and limited capacity to source that type of population. Online Creative Research Systems (1982) and Israel (2003) recognize such challenge in management and social researches and provide computational models for determining the study samples.

4.8.2 Sample size determination

Artificial neural network (ANN) requires a sizeable amount of data for prediction model to be developed. Since there is yet no recommended formula for computing sample sizes for artificial network (AN) prediction models, the study explored seven criteria for determining the sample size (SS). These are a sample size of similar past studies, study population size, the purpose of the study, level of precision and confidence, the degree of variability in the attributes being measured (Miaoulis and Michener, 1976) and survey response rate in the construction industry researches (Idrus and Newman, 2002). Israel's (2003) mathematical equation for determining sample size is presented in Equation 4.1.

$$SS = \frac{Z^2 x\, p\, x\, [1 - p]}{e^2} \qquad \text{Equation 4.1}$$

Where Z is the statistical value for the desired confidence level, 1.96 found in statistical tables at 95% confidence interval for a large and unknown population; *p* indicates the value of the population proportion which is being estimated; e (0.05) denotes the desired level of precision.

The value of *p* for unknown population size, taking a conservative value of 0.50, to ensure that a sample size as large as required be obtained. Taking a large and unknown population size for this study and 95% confidence level, substituting the values in Equation 4.1, the SS was approximated to 384.

SS = $[1.96^2 *0.5 * (1-0.50)]/0.05 *0.05$

= 384

Secondly, taking a cue from the sample sizes of past and similar studies; Squeira (1999) used the dataset of 75 building projects, Chen and Hartman (2000) used 80 projects. Emsley et al. (2002) used a dataset of 288 completed buildings, while Pewdum et al. (2009) used 51 data sets of highway projects. Wang et al. (2012) researched on construction cost schedule prediction with 92 datasets; Petruseva et al. (2013) researched on the prediction of duration of building projects in Bosnia and Herzegovina, used 75 buildings. Kaur (2016) demonstrated the effectiveness of artificial neural networks in project management, used 50 samples. Others are Mensah et al. (2016) - 18 completed bridge projects, Odeyinka et al. (2012) - 19 datasets, Alqahtani and Whyte (2013) - 20 buildings, Gunaydin and Dogan (2004) and Roxas and Ongpeng (2014) – 30 buildings each, Fachrurrazi and Munirwansyah (2017) – 40 datasets, Amusan et al. (2013b) – 50 samples, Aibinu et al. (2015) and Arafa and Aqedra (2011) – 71 datasets each, Maghraby (2009) – 80 building projects, Amusan et al. (2013a) – 100 samples, Al-Zwainy et al. (2012) – 150 samples, Goh and Chu (2013) – 160 samples, Kim et al. (2013) – 217 buildings, Najafi and Kong (2016) – 220 precast caeses, Abidoye and Chan (2017) – 321 cases and Kim et al. (2004) – 530 cost datasets.

To ensure the return of number that compared favourably with previous studies, an estimated number for administration was computed based on 530 datasets of Kim et al. (2004) and 30 % upper bound level of Idrus and Newman (2002) adequate percentage return in the construction industry. The study employed 30/100 E = 530, where E is the estimated number of the questionnaire = 1766.67. The estimated number (E) for distribution was approximated to 1800 questionnaires.

4.8.3 Sampling technique

Sampling method is the method used by the researcher to select the survey sample (Israel, 2003; Yusuf, 2013). There are two main types of sampling methods (1) probability sampling – based on chance events such as random numbers, flipping a coin. Random sampling comprising simple random sampling or stratified random sampling are probability sampling techniques. And (2) non-probability sampling – based on researcher's choice, a population that is accessible and available (Setia, 2016). Some of the non-probability sampling methods are; purposive sampling, convenience sampling, quota sampling, snowball sampling, volunteer sampling, matched sampling and genealogy-based sampling (Alvi, 2016).

Like Gebrehiwet and Luo (2017), purposive sampling technique was used in collecting the primary data. Secondary data on buildings completed within the last six years (2012 – 2017), comprising contract sum and final cost, estimated actual construction durations were obtained from the archives of construction professionals who participated in the survey. Primary data is referred to as empirical data sourced from the research participants or respondents, while secondary data are those obtained from published sources such as financial statements and company records. The research consent form and samples of the questionnaire (See Appendices II, III and IV) were first e-mailed to participants in management positions of some selected public establishments in Bauchi, Damaturu, Gombe, Jalingo, Maiduguri, Mubi and Yola. Others were self-administered to respondents in their offices in the state capitals and to the conference participants at the August 2017 Annual General Meeting/Conference of the Nigerian Institute of Building (NIOB) that held in Bauchi, a state capital in the study area.

4.9 Questionnaire administration and response

The selection of data type and the subjects from whom the data are collected is doned with sound judgment to avoid not only haphazardly (Bernard et al., 1986) but data collected from the wrong participants. The survey questionnaires were administered on construction professionals; architects, builders, civil/structural/services engineers, quantity surveyors, site supervisors and general foremen using purposive sampling method

Questionnaire distributions was first by electronic mailing followed with self-administrations across the states in the study area and in the NIOB conference centre. The distribution is shown in Table 4.7. 351 questionnaires representing 19.50% of the samples was distributed in Adamawa State, 249 representing 13.83% of the samples was distributed in Taraba State while 169 representing 9.39% was distributed in Gombe State.

Table 4.7: Questionnaire distribution

Study Area & Conference centre	Distribution method		Number distributed and % of total distributed	
	Self-administration across the study area	Electronic mailing	N	%
Adamawa State	322	29	351	19.50
Bauchi State	181	21	202	11.22

Study Area & Conference centre	Distribution method		Number distributed and % of total distributed	
	Self-administration across the study area	Electronic mailing	N	%
Borno State	0	9	9	0.50
Gombe State	157	12	169	9.39
Taraba State	240	9	249	13.83
Yobe State	0	13	13	0.70
Self-administration at Bauchi 2017			807	44.83
	Total number distributed		1800	100.00

Except the number distributed by electronic mailing system in Borno and Yobe States, where the insurgency of Boko Haram was most intense, there were no self-distributions in the two states due to tight security surveillance, any misunderstanding of the researcher's mission was carefully considered (Abolurin, 2012; Cohen and Cummins, 2002; Goodhand, 2000; Wood, 2006) and avoided. A total number of 294 questionnaires (See Table 4.8) which represents 16.33 % of the number distributed (1800) were received. It is shown in Table 4.9 that 294 samples were collated on state basis, out of which 246 (13.67%) were used for the analysis. Adamawa state was split into Adamawa North and Adamawa South to achieve similarity in the grouping (largest group/smallest group ratio ≤ 1.50) (Stevens, 1996). The difference resulted from mistakes, omissions and outliers which are extremely high missing items and low scores which were sorted out of the survey data collected.

Table 4.8: Research participants' response

Location	Number returned (N)	Percentage of total number distributed (%)	Invalid number & of number distributed		Valid number & of number distributed	
			No	%	No	(%)
Adamawa North	69	3.83	18	1.00	51	2.83
Adamawa South	68	3.78	7	0.39	61	3.39
Bauchi State	62	3.44	15	0.83	47	2.61
Gombe State	46	2.56	0	0.00	46	2.56
Taraba State	49	2.72	5	0.28	44	2.44
Total	294	16.33	45	2.50	249	13.83

The distribution and retrieval in Adamawa State is higher than in other states because of the relatively higher volumes of economic and construction activities in Yola, the state capital. Yola town was the capital of the defunct Gongola state from which Adamawa and Taraba States were created in 1991 (National Geospatial –Intelligence Agency [NGIA], 2004). The percentage of the returned questionnaire are; Adamawa South 61 which 3.39%, Adamawa North 51 which 2.83%, and Taraba 44 which is 2.44% of the total number distributed. The invalid (incorrectly filled) 45 or (2.50%) of the quantity distributed is high because the ambiguities in some could not be cleared from the research participants, who could not be traced due to ethical requirements observed in the instrument design.

Ankrah (2007) acknowledges the difficulty in obtaining a high level of response with questionnaire survey in the construction industry. Idrus and Newman (2002) had earlier considered 20% to 30% response rate adequate for researches in construction management. Chew et al. (2008) in China recorded 13.30 % (133/1000) on the core capability and competitive strategy for construction Small and Medium Enterprises (SMEs), slightly lower than the present study, while Tan et al. (2012) in Hong Kong had a slightly higher response of 19.60 % (61/312). Moreover, the 249 responses collated from responses lie in between the upper and lower bounds; it also lies between 18 and 530 datasets other researchers had used in previous and similar prediction studies using artificial neural network. Goh and Chu (2013) used 160 sample sizes for neural network analysis of construction safety management systems, Kim et al. (2013) used 217 buildings in the comparison of School building construction costs estimation methods using regression analysis, neural network and support vector machine. Najafi and Kong (2016) used 220 precast cases in productivity analysis of precast concrete constructions with artificial neural network. This study's sample was therefore adjudged adequate for use in the analysis because the sample size lies above 217 and 220 sizes used in similar studies Kim et al. [(2013) and Najafi Kong (2016)]

4.10 Data adequacy

Data adequacy is an overall determination of the degree of richness and the quantity of data supporting a review finding (Glenton et al. 2018). Data adequacy assessment aims at not judging whether adequacy has been achieved but whether there are ground for concern regarding adequacy that are serious enough to lower confidence in the research finding. Concerns about data adequacy arise when there are concerns about the richness or the quantity of the data in relation to the claims made in the research finding.

The GRADE-CERQual (Confidence in Evidence from Reviews of Qualitative Research) is an approach developed by the GRADE (Grading of Recommendations Assessment, Development and Evaluation working group. The approach which support the use of finding from qualitative evidence syntheses in decision making, including guideline development and policy formulation apart from adequacy of data has three other components. In this study, data adequacy was not considered an issue because quantitative evidences were used instead of qualitative evidences, where richness often serves as an important maker of data adequacy (Popay et al., 1998). The research data was considered rich and quantity adequate in relation to the reseach findings drawn in the data analysis Chapter 5.

4.11 Unit of analysis

Guided by the definitions and explanations of Collis and Hussey (2003), Teddie and Tashakkori (2009) and Trochim (2006) that entity, individual, group, phenomenon, social organization or artifacts investigated can be a research's unit of analysis. Project cost overrun, and time overrun, and cost and time performance are terms that feature prominently in this report and compete for attention for choice as unit of analysis of this research. Since overruns are in two directions; positive (overrun) and negative (underrun), none qualify for unit of analysis. Construction project performance in terms of coverage is central to this research, because the data that were collected from research participants, are first on the participants, next on construction cost and time and lastly on the driving factors. Data were analyzed for assessment of construction cost and time performance. The factors were on cost and time drivers that impact on performance, the models also designed for performance assessment. Therefore, unit of analysis of this research is construction project cost and time performance.

4.12 Methods of data analysis

Data were coded with IBM SPSS Statistics version 21. Mistakes, omissions and outliers which are extremely high and low scores were sorted out of the survey data, three more cases found with reasonable number of missing items were excluded from the 249 valid cases which further reduced the data to 246 that were used in the analysis.

4.12.1 Group mean scores and 80/20% Pareto rule

Pareto analysis a formal technique developed by an Italian economist and sociologist Vilfredo Pareto (1848-1923) is useful where many possible causes compete for attention. The principle states that 80% of consequences stems from 20% of the causes or that 20% of the invested input is responsible for 80% of the results obtained (Grosfeld-Nir et al., 2007; Robert, 1987; Svenssson and Wood, 2006). Its use resulted in the improvement of rapid application development model for a firm that focused on fewer activities yielding 80 percent of the overall productivity and since been recommended (Rizwan and Igbal, 2011).

The data was grouped based on construction project stakeholders; clients, consultants, main contractors, subcontractors and suppliers. The mean scores were computed for cost and time factors. The group mean scores were computed using a combination of IBM SPSS Statistics version 21 and Microsoft Excel. By the Pareto rule, the top nine (9) (43 x 0.20) and ten (10) (49 x 0.20) factors were identified as significant drivers of construction cost and time respectively.

4.12.2 Factor analysis (FA)

The term factor analysis encompasses a variety of related techniques comprising factor analysis (FA) and principal components analysis (PCA) which are similar and often used interchangeably. Both techniques attempt to produce a smaller number before their use in other analysis as multiple regression, multivariate analysis of variance (Pallant, 2010) and the design of artificial neural networks. However, they differ in several ways, in factor analysis; factors are estimated using a mathematical model, whereby only the shared variance is analyzed. In principal components analysis (PCA) the original variables are transformed into a smaller set of linear combinations, with all the variances in the constructs used (Ganiyu and Zubairu, 2010; Hair et al., 2010; Tabachnick & Fidell, 2007). Although both techniques (PCA and FA) often produce similar results, Tabachnick and Fidell (2007) admits preference for factor analysis because it is a better choice when the interest is an empirical summary of the large dataset. The authors also recommend FA to researchers whose interest is in a theoretical solution free from errors. Stevens (1996) admits a preference for principal component analysis because it is psychometrically sound and simpler mathematically. Secondly, it avoids some of the potential problems for example factor indeterminacy which is usually associated with factor analysis. The factor analytic techniques are also used for the development and evaluation of tests and scales. The techniques are data reduction methods that take large set of variables and reduce or summarize into smaller set factors or components. The reduced components are simply linear combinations of the original variables. PCA was used in this research to reduce the 43 and 49 cost and time factors into few related components in the data analysis Chapter 5.

The two main approaches to factor analysis are exploratory and confirmatory factor analysis. Exploratory factor analysis is often used in the early stages of research to source information about the interrelationships among sets of variables. Confirmatory factor analysis is a more complex and sophisticated sets of techniques used at the tail end of research processes to test or confirm specific hypotheses or theories concerning the underlying structure in a set of variables. Kim et al. (2008) stated the main benefits of factor analysis: (i) exposing the hidden dimensions or constructs which may or may not be apparent from direct analysis (ii) identification of groups of inter-related variables to see their relationship (iii) focusing the analyst's attention on the unique core elements instead of the redundant attributes (iv) reduction of number of variables by combining two or more variables into a single factor-component. Like Oyewobi (2014) this study used Principal Component Analysis (PCA) technique to reduce the 43 and 49 cost and time factors to a few uncorrelated components in the data analysis Chapter. Conducting PCA involves the following three steps;

4.12.2.1 Assessment of the suitability of the data for factor analysis

Two issues are considered in determining if a dataset is suitable for FA or not. The issues are sample size and strength of the relationship among the variables or items, the larger the sample, the better because the correlation coefficients among smaller variable datasets are less reliable, the coefficients tend to vary from sample to sample. Moreover, factors obtained from small datasets do not generalize as those derived from larger samples. Tabachnick and Fidell (2007) recommend between 300 and 150 cases where the solutions have several high loading marker variables (above 0.8) or 5 cases for each factor, item or variable. Nunnally (1978) recommends 10 cases to 1 factor to be analyzed.

The second issue is the strength of the inter-correlations among the factors indicated by the magnitude of the correlation coefficient. Tabachnick and Fidell (2007) recommends an inspection of the correlation matrix output Table for evidence of coefficients greater than 0.3. If few correlations above 0.3 are found, factor analysis may not be appropriate. Bartlett's test of sphericity (Bartlett, 1954) and Kaiser-Meyer-Olkin (KMO) two statistical measures generated by SPSS to assist in assessing the data factorability. Bartlett's test of sphericity should be significant at ($p < 0.05$) for the factor analysis to considered appropriate. The KMO's index ranges from 0 to 1 with 0.6 suggested as the minimum value for a good factor analysis (Tabachnick and Fidell, 2007).

Other peculiar assumption that the data must satisfy for factorability are linearity and outlier-proof. Since factor analysis is based on correlation, it is assumed that the relationship between the variables is linear. Factor analysis is sensitive to outliers (Odeyinka et al., 2012).

Data for this study were subjected to the test's assumptions discussed above. Bartlett's test of sphericity displayed in the SPSS output table is significant ($p < 0.000$) while KMO indices are 0.766 and 0.785 for construction cost and time data respectively (See Appendices VI and XIII). The removal of outliers (extreme data) reduced the data sizes from 246 to 209 for cost data 198-time data.

4.12.2.2 Factor extraction

This entails determining the smallest number of factors that can be used to best represent the interralationships among the set of variables. Approaches for extracting the underlying factors or dimensions are principal components, principal factors, image factoring, maximum likelihood factoring, unweighted least squares and generalized least squares. The most commonly used is principal component analysis. The considerations are the need to (i) find a simple solution with fewest possible factors (ii) to explain as much of the variance in the original dataset as possible. Therefore, different numbers of factors are experimented with until a satisfactory solution is found. The technique of deciding the number of components to retain is run in the following order; Kaiser's criteria, Scree test and parallel analysis.

a. Kaiser's criteria or eigenvalue rule; In this rule only the factors with an eigenvalue of 1.0 and above are retained for further investigation. The eigenvalue of a factor represents the amount of total variance explained by that factor. This is not popular because it retains too many factors in some situations.
b. Scree test; Catell (1966), Howard (2016), Ledesma et al. (2015) plotting each of the eigenvalues of the factors and inspecting the plot to find a point at which the shape of the curve changes direction and becomes horizontal. Ledesma et al. (ibid) recommends retaining all factors above the elbow or break in the plot. Such factors contribute the most to the explanation of the variance in the dataset.
c. Parallel analysis; Horn's (1965) parallel analysis involves comparing the size of eigenvalue with those obtained from a randomly generated dataset of the same size. Only those eigenvalues that exceed the corresponding values from the random dataset are retained. The approach to identifying the correct number of components to retain has been shown to be the most accurate, because Kaiser's criterion and scee test tend to overestimate the number of components (Hubbard and Allen, 1987; Velicer, 1986).

On the study being reported, the datasets were taken through Kaiser's criteria or eigenvalue rule, Scree and Parallel analysis to decide on the factors' extraction number. Using the IBM SPSS statistics version 21 the tables of outputs for construction cost and time factors are presented in Appendices VI to XIX. The tables are cost and time factors' Scree plots, factors' initial or PCA total variances explained, comparison of eigenvalues from principal component analysis and criteria values from parallel analysis, parallel analysis total variances explained and component correlation matrices of the reduced component.

In this procedure, the list of eigenvalues provided in the Total Variance Explained and some additional information from another little statistical program (https://download.cnet.com/Monte-Carlo-PCA-for...) developed by Watkins (2000) were used. A link was followed to the additional material site to download a zip file (parallel analysis.zip). This was unzipped to the MonteCarloPA.exe PCA for Parallel Analysis. The programme asked for three pieces of information: the number of variables being analyzed (in this case, 43); the number of participants in the sample (in this case, 209); and the number of replications (100 was specified). It gave a behind the scenes calculation to generate 100 sets of random data of the same size as the real data file (43 variables × 209 cases). It calculated the average eigenvalues for these 100 randomly generated samples (See Appendix IX). The first eigenvalue obtained in SPSS were compared with the corresponding first value from the random results generated by parallel analysis. Where the values are larger than the criterion value from parallel analysis, the component was retained and rejected where it was less.

4.12.2.3 Factor rotation and interpretation

Next is the interpretation of the components. The factors are rotated to present the pattern of loadings for easy interpretation. The SPSS software shows which factors or variables, or items clump together. Two main approaches to rotation are orthogonal or uncorrelated and oblique or correlated factor solutions. Orthogonal rotation results in solutions that are easy to interpret and report, but the draw back is that the researcher is required to assume that the underlyingconstructs are independent or not correlated. In most times the assumption has been found incorrect (Tabachnick and Fidell, 2007). The two often result in similar solutions, particularly when the pattern of correlations among the factors or items is clear (Pett et al., 2003, Tabachnick and Fidell, 2007). Pallant (2010) recommends rotation commencing with an oblique rotation to investigate the degree of correlation between factors. SPSS provides between the two broad categories of rotation techniques for example Orthogonal – Varimax, Quartimax, Eqamax and Oblque – Direct Oblimin, Promax. The commonest orthogonal approach is orthogonal varimax method which minimizes the number of variables that have high loadings on each factor. That of Oblique is Direct Oblimin. On rotation the result is what Thurstone (1947) refers to as simple structure. This means each of the factors (variables) loaded strongly on only one component and each component represented by several strongly loading variables. Variables that load strongly on each component ease the interpretation of the factors' nature (Pallant, 2010).

Oblique direct Oblimin rotation was adopted in the study. The variables loaded strongly on each of the five and seven cost and time components. Some variables were deleted due to no loading or weak loading by the inspection of the coefficients in the output Tables: pattern, structure matrices and communalities. These are discussed in the next chapter which is devoted to data analysis. The extracted components of the construction cost and time constructs were named and interpreted based on stakeholders' contractual parties' responsibilities on a construction project.

4.12.3 Analytical techniques used in comparing groups

There are many statistical analytical techniques used in comparing groups. Some of such techniques are; (i) independent – samples t-test, (ii) paired – samples t – test, (iii) one – way between-groups ANOVA, (iv) one – way repeated – measures ANOVA, (iv) two – way analysis of variance (between groups), (v) mixed between – within groups ANOVA, (vi) multivariate analysis of variance (MANOVA) and (vii) Analysis of covariance. Each of the techniques has its suitability for some specific research objective and hypothesis.

4.12.3.1 One-way between-groups ANOVA with post-hoc test

The one-way between-groups or post-hoc comparisons (also known as posteriori) is used for conducting sets of comparisons to explore differences between groups (Ankrah, 2007; Pallant, 2010). More specifically the technique is used where the differences in performance is likely influenced by one group or location on another.

The analysis consists of two steps. First, an overall *p*-value tells whether there are any significant differences among the groups. The *p*-value (probability) displayed in the output table measures the likelihood that a finding or observed difference is due to chance. The *p*-values normally are between 0 and 1. The closer the result is to 0, the less likely it is that the observed difference is due to chance (significant reject H_0). The closer the result is to 1 (not significant-accept H_0), the greater the likelihood that the finding is due to chance (random variation) and that there is no difference between the groups/variables. If the overall *p*-values is significant indicating that there are differences among the groups, additional tests can be performed to identify where these differences occur (for example, does Group 1 (State 1) differ from Group 2 (State 2) or Group 3 (State 3), do Group 2 (State) and Group 3 State 3 differ? (Pallant, 2010). Post-hoc comparisons are designed to guard against the possibility of an increased Type 1 error due to many different comparisons made. This is done by setting more stringent criteria for significance, and therefore it is often harder to achieve significance. With small samples, this can be a problem, as it can be difficult to find a significant result even when the apparent differences in scores between the groups are quite large. Some assume equal variances for the groups (e.g. Tukey); others do not assume equal variance (e.g. Dunnett’s C test). Two of the most commonly used post-hoc tests are Tukey’s Honestly Significant Different test (HSD) and the Scheffe test. Of the two, the Scheffe test is the most cautious method for reducing the risk of a Type 1 error, though there is less likelihood of detecting a difference between groups.

Much consideration is given to the test power to correctly identify if truly there is difference between the groups in one-way between-groups ANOVA with post-hoc test. This is because the power test analysis gives an indication of how much confidence should be reposed in the results especially where the null hypothesis was not rejected. The higher the power, the more confident that there is no real difference between the groups. This power of test is investigated because it is influenced by the sample size. This is not a challenge when the cases are 100 and above. But with a sample size as small as 20, it is certain that a non-significant result is due to the insignificant power. The remedy is firstly, adjust the alpha level to compensate where the group sizes are involved, this means setting a cut off 0.10 or

0.15 rather than the traditional 0.05 level. Secondly, is the effect size, this means the strength of the difference between groups or influence of the independent variable. Some effect sizes are given in Cohen (1988) (See Table 4:9) which are the tabulated statistical classifications of Eta Squared, the measure of effect size that ranges from small, medium and large. The effect sizes are listed against the corresponding statistical measures. The third influence on the power of test is the alpha level which could be set at 0.15, 0.10 and 0. 05.

Table 4.9: Eta Squared and Cohen's (1988) classifications for group comparison

Effect size	Eta Squared (% of variance explained)	Cohen (Standard deviation units)
Small	0.01	0.2
Medium	0.06	0.5
Large	0.138	0.8

Source: (Pallant, 2010:210)

The value can be computed using the Kondo-Brown and Fukuda (2008) formula which equals Sum of squares between groups divided by the Total sum of square. The SPSS procedures provide an indication of the power of the test using effect size and sample size. One-way between-groups ANOVA with post-hoc test was used in this study first for comparing construction project cost and time overruns means between each of the states in the study area, if a relatively more developed state capital influences the scores of other less developed state capitals. The groups in the research objective number two refer to Adamawa North, Adamawa South, Bauchi, Gombe and Taraba States in North eastern Nigeria. Secondly, for investigating the construction project cost and time performance differentials among three classifications or groups of project complexity classifications; small or uncomplicated projects, medium or moderately complex and large or complex projects. The general and specific assumptions upon which one-way between-groups ANOVA with post-hoc tests are founded as highlighted by Pallant (2010) are herein itemized. Compliance of the survey data with the assumptions was investigated prior to analysis in the data analysis Chapter.

Level of measurement

All parametric techniques for group comparison assume that the dependent variable (overruns in this research) are measured on interval or ration scale. This means a continuous scale rather the discrete categories (See section 2 of the data collection instrument in Appendix IV).

Random sampling

The parametric techniques assume that the scores were obtained with a Radom sampling technique from the population, Gravetter and Wallnau (2004) noted the practical infeasibility of data satisfying this assumption.

Independence of observations

Observations that make up the data must be independent of one another. This means each observation or measurement must not be influenced by another observation or measurement.

Violation of this assumption according to Stevens (1996) and Gravetter and Wallnau (2004) can impair the test results.

Normal distribution of scores
It is assumed always in parametric statistics that the population from which the samples were taken are normally distributed. In many researches particularly the social sciences, scores of the dependent variable are not normally distributed. Fortunately, most of the techniques are reasonably tolerant of violation of this assumption. With large samples of 30 and above, the violation may not be an issue.

In this study, there were no major deviations from normality as the points on the Normal P – P plots lie in a straight diagonal line from bottom left to top right as seen in the output graphs -Appendices XXVIIIa and XXVIIIc) for both cost and time variables. On the scatter plots of the standardized residuals, the points are roughly rectangularly distributed with most scores concentrated in the centre (output graphs Appendices XXVIIIb and XXVIIId) for the cost and time variables. These indicate non-violation of normality of the data used in the analysis.

Homogeneity of variance in the populations
This concern the assumption that samples are obtained from populations of equal variances. This means that variability of scores for each of the groups is similar. IBM SPSS Statistics version 21 performs Levene's test for equality of variances as part of the ANOVA. The results are presented in the output (See Table 5.11), a significance level of less than 0.05 suggests that variances of the groups are not equal and therefore a conclusion on violation of the assumption. Notwithstanding, the technique is tolerant of the violation provided the group size is reasonably similar, for example largest group/smallest group ≤ 1.50 (Stevens, 1996).

4.12.3.2 Procedure adopted in the conduct of this study's one-way between-groups ANOVA with post-hoc test
Oyewobi (2014) used one-way ANOVA to investigate whether the means of performance and the generic strategies differed between the groups in his study. In a similar mode, post-hoc comparison was used in the study to investigate the cost and time overrun means and as well as differences between the means among the locations in the study area. The independent variables or factors; Adamawa North, Adamawa South, Bauchi State, Gombe and Taraba States, while the dependent variables are cost and time overruns. IBM SPSS statistics version 21 was used in the evaluation at 5% level of significance and a 2-sided test on the collected data. The equal variances assumption for the groups was satisfied and Tukey's Honestly Significant Different test (HSD) was used in the post-hoc test. The Levene's test for equality of variances significance value was less than 0.05, in both cost and time constructs suggesting that variances for the groups are not equal and a violation of the assumption of homogeneity of variance. Stevens (1996) however, posits that when the similarity (largest/smallest of the group size) is less than or equal to 1.5, the violation is nullified. The computed group size similarity for this study is 1.50 (69/46) from the returned questionnaire, the statistic was improved to 1.40 (61/44) on removal of the invalid numbers, the Post-hoc test therfore proceeded.

Post-hoc power (observed power) or the statistical power of the tests are normally based on the inherent effect size estimate of the data i.e the probability of finding a statistical difference in a test (significant effect) if there is a true difference. Post-hoc power differs from the true power of the test because the true power depends on the true effect size. However, the true effect size is typically unknown, and therefore the temptation of treating post-hoc power as if it is the true power was avoided in this study. The observed power (or post-hoc) was computed in the study using information from the SPSS output tables. The post-hoc power and *p*-values given in the SPSS output tables are, however, directly related (Hoenig & Heisey, 2001).

4.12.3.3 One-way repeated measures ANOVA

In a one-way repeated measures ANOVA design, each subject is exposed to two or more conditions or measured on the same continuous scale on three or more occasions. The technique can also be used to compare respondents' responses to two or more different questions or items (Pallant, 2010). The technique tells if there is a significant difference somewhere among the three sets of scores (Hair et al., 2010). Wilks' lambda is one of the four multivariate tests: Pillai-Bartlett trace, Hotelling-Lawley trace or Roy's largest root. These alternatives are appealing because they do not make the strict, often unrealistic, assumptions about the structure of the variance-covariance matrix. The information is provided in the pairwise comparison table which compares each pair of points and indicates whether the difference between is significant. This is indicated on the sig column (Kristensen and Hansen, 2004).

The technique was adopted for investigating the change in cost and time performance across the three groups of construction project complexity classifications (uncomplicated, medium complex and largely complex projects) in the study area. The values of interest in the SPSS tables of outputs is the Wilks' Lambda and the associated probability value shown in the Multivariate tests output table. All the multivariate tests statistics yield the same result, but Wilks' Lambda is the most commonly reported (Stevens, 1996). Decisions are based on the p-value, if it is less than 0.05, the conclusion is drawn that there is a statistically significant difference across the three different groups (Tabachnick and Fidell, 2007). Though a conclusion may have been drawn on the statistically significant difference between the groups of scores, there is still a need to assess the effect size of the result which is indicated by the Partial Eta Squared statistic in the Multivariate tests output table.

Although Hass (2016) classify construction projects into three, Altshuler & Luberoff's (2003) \$250 million minimum contract sum for large or complex projects which aligns with Randolph et al.'s (1987) earlier three classifications of; small (less than \$50 million) medium (between \$50 and \$250 million) and largely complex (\$250 million and above) were adopted for use in the study. Hass' (2016) (independent project or low complexity projects of less than \$250 million with less than three months construction duration, moderately complex projects of between \$250 and \$750 million and construction duration of three to six months and highly complex projects of \$750 million and six months and above contract duration) were found unsuitable because of the low construction duration classifications. A combination of Altshuler & Luberoff's (2003) and Randolph et al.'s (1987) complexity yardsticks together with the 2003 United States of America construction cost per square metre ($1,077.33/m^2) [US-DHUDOPDROH] (2005) vise-a-vice the 2003 Nigerian construction cost per square metre (N35,000.00/m^2) (Windapo, 2005) were used. After converting the 2003 United States of America dollar values to their respective floor area coverages, the areas were thereafter converted to total cost using the Nigerian 2003 construction cost per square. The 2003 Nigeria construction cost per square metre was first raised to year 2018 cost value, taking into consideration the inflation rate between the base year 2003 and 2018 by the application of the respective price indices obtained from (Nigeria Bureau of Statistics, 2018). The survey data classification into groups of small or uncomplicated, medium or moderately complex and largely complex projects were thus achieved. The tests for construction project complexity impacts on cost and time performance in the study area were therefore conducted and presented in the data analysis Chapter using SPSS and Microsoft Excel 2016.

4.12.4 Simple correlation and multiple linear regression modelling processes

Adebakin (2013) and Pallant (2010) correlation analysis is used to describe the strength and direction of the linear relationship between two variables. Correlation coeffi cients (r) take on values from –1 to +1. The positive or negative sign indicates whether there is a positive correlation (as one variable increases, so too does the other) or a negative correlation (as one variable increases, the other decreases). The size of the absolute value (ignoring the sign) provides an indication of the strength of the relationship. A perfect correlation of 1 or –1 indicates that the value of one variable can be determined exactly by knowing the value on the other variable. A scatterplot of this relationship would show a straight line. A correlation of 0 indicates no relationship between the two variables. Knowing the value on one of the variables provides no assistance in predicting the value on the second variable. A scatterplot would show a circle of points, with no pattern evident. The value can be computed for Pearson product-moment correlation coefficient (r) or Spearman Rank Order Correlation (rho). Pearson r is designed for interval level (continuous) variables while Spearman rho is designed for use with ordinal level or ranked data and is particularly useful when the data does not meet the criteria for Pearson correlation (Akinbile, 2013). In this research, Spearman rho correlation coefficient was used in investigating the internal validity of the questionnaire items of the data collection instrument

Multiple regression or multivariate regression (Gelman and Hill, 2007) is an extension of simple correlations analysis, the technique allows for more sophisticated exploration and real-life situation of the interrelationship among sets of variables. Multiple regressions tests are ideal for the investigation of complex real-life research questions (Gelman and Hill, 2007; Pallant, 2010). The predictive power of sets of variables and assessment of the relative contribution of each individual independent variable (Alabi and Falola, 2013; Kerlinger and Lee, 2000; Pallant, 2010) in the dependent variable are achieved with MLR. Thus, the technique is basically the derivation of an equation for example:

$$y = a + b_1x_1 + b_2x_2 + ...b_nx_n + e \qquad \text{Equation 4.2}$$

Each predictor/input/independent/explanatory variable (x) has its own coefficient for example 'b_1, b_2 ...bn' in Equation 4.2. The dependent variable/response/output (y) is predicted from a combination of all the variables multiplied by their corresponding coefficients plus the residual term (a) and an error term or stochastic disturbance (e) (Alabi and Falola, 2013; Field, 2013; Stock and Watson, 2006).

The MLR technique was used in investigating two of the study's research hypotheses stated in Chapter Three, section 3.5; H_{2a} the relationship between cost impact and the influence of the intervening cost driving factors of public building projects and H_{2b} the relationship between time impact and the influence of the driving the factors. Coefficients of determination (R-Square) between impacts and driving factors' influence indicate the extent to which all the independent variables taken together assist in predicting or explaining the variance in dependent variable (Pallant, 2010). The level of significance indicated by the Sig value is important for ascertaining whether the value could have arisen by chance. The significance of the R-Square value at 0.05 alpha leads to confidence in the interpretation of the correlation even to the population from which the sample was taken. Standard multiple regression technique was used in investigating the relationships between impacts and the driving factors' influence. This is because it enables each independent variable to be evaluated in terms of its predictive power, over and above that offered by all other independent variables, moreover, how much unique variance in the dependent variable each of the independent variables explains (Pallant, 2010; Alabi and Falola, 2013).

IBM SPSS Statistical version 21 was used in analyzing the survey data. The relationship tests result for the cost and time impacts and their influence factors are presented in the data analysis Chapter Five. The values of R-Square of both cost and time though small are positive values which were used in the multiple linear regression cost and time impact prediction model development (Moore and McCabe, 1989). The sig values tended towards the acceptance of H_0 (no significant relationship) though the R-square values are positive (Moore and McCabe, 1989, Morenikeji, 2006). The smallness of the R-squared values thus suggested the inability of the independent variables' (significant factors) to sufficiently pattern the relationship between the dependent variable (impact) and the independent variables (factors' influence).

4.12.4.1 Test for data satisfaction of multiple linear regression assumptions

The survey data for developing the construction MLR cost and time impact models were tested for non-violation of multiple linear regressions' assumptions prior to to analysis. The purpose is to answer the main research hypothesis that;

The direct relationship between the intervening factors' influence and the cost and time impacts can be used to design cost and duration impact assessment models within certain confidence level.

The data comprised 209 cost cases and 198-time cases cleansed from outliers. The significant influence factors determined earlier are 9 significant cost factors and 10 significant time factors. The test results of data satisfactions of MLR assumptions are presented in the following Table 4.10 and Appendices XXVIIIa to XXVIIId.

Table 4.10: Data test results for non-violation of multiple linear regressions assumptions

S/No	Cost factors	Time factors
1	Number of cases N (209) > 50 + 8m (Tabachnick and Fidell, 2007). Where m is number of significant factors, N number of cases or case quantities. 50 + 8 *9 = 122 Number of cases to be greater than 15 cases or participants per predictor variable Stevens (1996). 209 > 15 * 9 = 135 Alabi and Falola's (2013) recommended the total number of cases be higher than the number of variables by 1. 209 > 43	Number of cases N (198) > 50 + 8m (Tabachnick and Fidell, 2007). Where m is number of significant factors, N number of case or quantities 50 + 8* 10 = 130 Number of cases to be greater than 15 cases or participants per predictor variable Stevens (1996). 198 > 15 * 10 = 150 Alabi and Falola's (2013) recommended the total number of cases be higher than the number of variables by 1. 198 > 49
2	Tolerance (> 0.10) (Pallant, 2010). SPSS output table values ranged between 0.782 – 0.882	Tolerance (> 0.10) (Pallant, 2010). SPSS output table values ranged between 0.757 – 0.808
3	Correlations between dependent and independent variables: Typical value 0.201	Correlations between pairs of dependent and independent variables: Typical value 0.156
4	Correlation between each pair of independent variables < 0.70 (Pallant, 2010). Typical value ≤ 0.355	Correlation between each pair of independent variables < 0.70 (Pallant, 2010). Typical value ≤ 0.355
5	Variance Inflation Factor (< 10) (Alabi and Falola, 2013; Pallant, 2010). 1.133 – 1.188	Variance Inflation Factor (< 10) (Alabi and Falola, 2013; Pallant, 2010). 1.113 – 1.320
6	Critical values of chi-square χ^2 using Table C.4 at 9 degrees of freedom and α = 0.001 Tabachnick and Fidell (2007). 27.877 > programme value 25.68	Critical values of chi-square χ^2 using Table C.4 at 10 degrees of freedom and α = 0.001 Tabachnick and Fidell (2007). 29.588 > programme value 27.49

On the number of cases for model development (respondents' completed questionnaire), Tabachnick and Fidell (2007) recommend the following model; N > 50 + 8m for the case quantities. Where N is the number of cases and m the number of significant factors. Case quantities for cost factors 209 is above 122 and time factors 198 also above 130. Another criterion is Stevens' (1996), which recommends 15 participants per predictor, this research's cost and time case quantities are above 135 and 150 respectively by that recommendation. The sample sizes also satisfy Alabi and Falola's (2013) recommendation that the total number of cases to be higher than the number of variables by 1. In this research the variables are 43 costs and 49 time, the requirement is also met in the samples.

On multicollinearity, collinearity diagnostics and singularity assumptions, prior to the administration of the questionnaire, the instrument was scrutinized and moderated by the main and co-supervisor, proofing it of singularity characteristic. An inspection of the SPSS correlation output Tables showed positive and negative low values of Pearson correlation coefficients between the dependent and independent variables (typical value 0.201 in the cost variables and 0.156 in the time variables). But, between each independent variable, the values were not higher than 0.355 for both cost and time constructs which were not more than 0.7, the recommended statistic. Notwithstanding the low dependent to independent variable correlation coefficients, the Tolerance (T) values ranged between 0.782 – 0.882 which are all above 0.10 and variance inflation factor (VIF) ranged between 1.133 – 1.188 also below 10 in the cost and time variables. The time variables also satisfy both assumptions, Tolerance is between 0.757 – 0.898 above 0.10 and the VIF, 1.113 – 1.320 below the recommended 10. The statistics indicate absence of multicollinearity issues in the data (Pallant, 2010; Alabi and Falola, 2013).

There were no major deviations from normality as the points on the Normal P – P plots lie in a straight diagonal line from bottom left to top right (See output graphs in Appendices XXVIIIa and XXVIIIc) for both cost and time variables. On the scatter plots of the standardized residuals, the points are roughly rectangularly distributed with most scores concentrated in the centre (see the IBM SPSS Statistics version 21 output graphs Appendices XXVIIIb and XXVIIId) for the cost and time variables. These indicate non-violation of normality, linearity and homoscedasticity. There are a few extreme points on the Scatterplots of the standardized residuals (outliers). The residuals are roughly rectangular in the distributions. Most of the scores are concentrated in the centre along with the zero point, indicating the low presence of outliers (Tabachnick and Fidell, 2007) and hence no violation of the assumptions. Absence of outliers in the datasets was also checked by the inspections of Mahalanobis distances produced by the multiple regression programs (SPSS) beside the data file in SPSS data view window.

Using Tabachnick and Fidell (2007) the values from Table C.4 (Critical values of chi-square χ^2) at 9 and 10 degrees of freedom and $\alpha = 0.001$, are 27.877 and 29.588 for the cost and time construct respectively. Whereas the maximum values displayed on the SPSS program are 25.68 and 27.49 for cost and time respectively. The statistics are below the critical values. There were no strange cases detected by the inspection of Cook's distances because none of the values was up to 1. The survey data were adjured fit for use to develop the MLR cost and time impact prediction models

4.12.4.2 Using multiple linear regression to develop the construction cost and time impact models

Based on the survey data satisfactions of the assumptions of multiple linear regression (MLR) technique, *past project statistics comprising initial contract sum/final cost, estimated and actual construction duration and the intervening cost and time factors' influence were taken forward for use as variables for the design of MLR cost and duration impact prediction models within certain confidence level.* Ijigah et al. (2012) designed cost overrun model but not with the construction stage driving factors. The significant nine and ten cost and time factors extracted from a total of 43 cost variables and 49-time variables were used in the design of impact prediction models. SPSS output tables of models' coefficients where the input variable coefficients were selected into the general linear regressions Equations 5.1 and 5.3 to build the linear regressions cost and time impact prediction models (Equations 5.2 and 5.4) are presented in Chapter Five. Following this study's view in the research concept presented in Chapter Three, ANN is an advanced (Gbahabo and Ajuwon, 2017) alternative tool to MLR, the possibility of adapting ANN into construction project cost and time performance assessment is discussed in the following sections.

4.12.5 Adopting the predictive ability of artificial neural network (ANN) into construction project performance assessment

The relationships between cost/time impacts and the driving factors' influence have been described as stochastic, nonlinear (Odeyinka, 2003) or curvilinear. Therefore, the fundamental assumptions of MLR based on linearity make the technique inappropriate for modelling construction cost and duration impacts with the driving factors' influence (Kim et al., 2004; Tam and Fang, 1999). This informed the paradigm shift to better alternatives of machine learning prediction techniques.

As stated previously, the most important feature of artificial neural networks is its adaptive nature, where learning by example from past projects replaces programming in solving problems and generalize solutions for future projects (Datt, 2012; Elhag and Boussabaine, 1998; Jha, 2016). The study holds the view that the advantages of data training and pattern learning ability of ANNs can be brought to bear on the assessment of construction cost and time driving factors' influence. In other words, historical data on project cost and time differentials caused by the driving factors' influence if sourced on several completed projects and mined in ANN software as input (independent) and output variables (dependent variables) can result in network models. Such models envisaged in this study are cost or duration impact predictions.

Like the multiple linear regression's equations, the artificial adopts similar forecasting models for construction project cost and time performance. The regressions are expressed with Equations 4.3 for cost impact and 4.4 for time impact. The difference is the ability of ANN to adjust the coefficients in the process of pattern learning as the model train and learn based on examples given.

Cost performance:

$Z_c = \beta + C_1Y_1 + C_2Y_2 + C_3Y_3 + \ldots + C_nY_n$ …………………………………… Equation 4.3

Where Z_c = Construction cost performance impact – measured in percentage; difference between initial contract sum and final cost

β = constant

$C_1, C_{2\ldots}\ C_n$ = Coefficients

$Y_{1,}\ Y_{2\ldots}\ Y_n$ = cost factors' influence.

Time performance:

$Z_t = \alpha + T_1X_1 + T_2X_2 + T_3X_3 + \ldots + T_nX_n$ ……………..Equation 4.4

Where:

Z_t = Construction time performance impact – measured in percentage; difference between estimated construction duration and actual duration
α = constant
T_1, T_2... T_n = Coefficients
X_1, X_2...X_n = time factors' influence

The weaknesses of MLR equations cannot be overemphasized; the linear relationship between the predictor variables which they assume, and the inability of capturing multiple input factors. This research opines that the resources for erecting the building project are inherent in the complete designs and even are quantifiable for use in planning, monitoring and control. However, given the prevailing economic reality and the current level of knowledge in construction project management, precise additional cost and time eventuated by construction stage exigencies are currently being determined inaccurately (Aiyetan et al., 2012; Izam and Kolawole, 1998; Jarkas, 2016; Mbachu, 1998, Olawale and Sun, 2010). Adapting ANN technique into construction project cost and time impact prediction would result in impact models of higher prediction efficacies than Multiple Linear Regression models. Therefore, turning the parameters of Equations 4.3 and 4.4 for ANN input and output variables from project historical cost and time data would produce more effective predictive models for forecasting the impacts of construction cost and time influencing factors on the bills of quantities' estimates. ANN adaptability is discussed and illustrated specifically with respect to cost and duration impact predictions in the following sections.

4.12.5.1 Adapting artificial neural network (ANN) system for construction cost impact predictions

As conseptualised in section 3.9, the advantages of ANN in forecasting can be brought to bear on the cost impact predition of public building projects in the study area by the demonstration of the operating system in the following Figure 4.3. The activity of the input units represents the raw information that is fed into the network (the independent variables 1, 2 and 3). That of the hidden unit (HN1 and HN2) is determined by the activities of the input units and the weights (W_{11}, W_{12}… W_{32}) (synapses) on the connections between the input and the hidden units, while the output Z_t is summed up by HN1, HN2, and the weights V_1 and V_2. The behaviour of the output units depends on the activity of the hidden units and the weights between the hidden and output units (V_1 and V_2). The weights in the interconnections manipulate the data to make calculations (Miller, 2015).

The neural network is empirically derived rather than theoretical (Setyawati et al., 2002). The sum of all weighted inputs determines the degree of activation level that is further modified by an activation function to produce the output signal expressed as ($\sum f$). Normally the general regression equation is expressed as;

$Z_t = \beta + C_1Y_1 + C_2Y_2 + C_3Y_3 + \ldots + C_nY_n$ ....Equation 4.5.

Referring to ANN architecture (Figure 4.3) the output Z_t is a sum expresses as;

Z_t (output) = aA + bB + cM...Equation 4.6

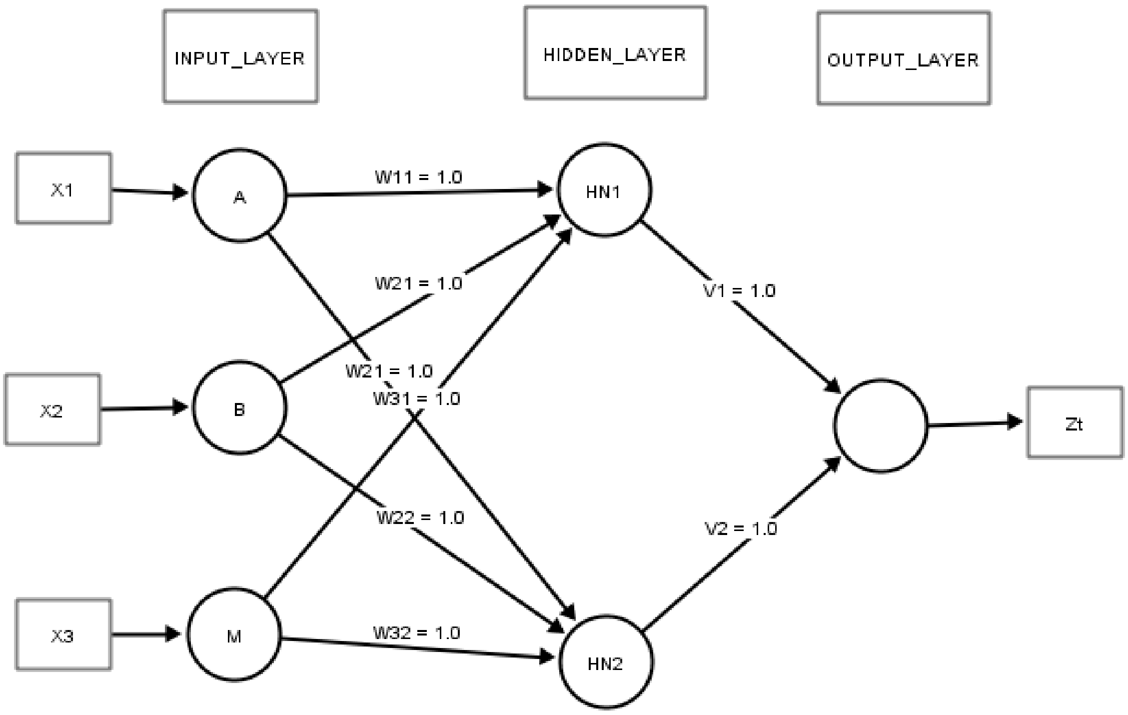
Which is the summation of all entries up to the hidden neurons (HN1 and HN2) in Figure 4.3 represented by the following equations;

$Aw_{11} + Bw_{21} + Mw_{31} = HN1$

$Aw_{12} + Bw_{22} + Mw_{32} = HN2$

From the mid-point of the structure, the addition of entries up to the output neuron is represented in the following equations;

$Z_t = V_1HN1 + V_2HN2$



KEY	
W_{11} to V_2	The connection weights
$\sum f$	A transfer function
●	Neurons that perform no calculations
○	Neurons that perform summations and functions
The output is input to the next year	

Figure 4.3: ANN input and output data mapping typical of cost impact assessment modelling (Source: Adapted from Kim et al., 2004:1236)

By expansion;

$Z_t = V_1 [Aw_{11} + Bw_{21} + Mw_{31}] + V_2 [Aw_{12} + Bw_{22} + Mw_{32}]$

$Z_t = (V_1 w_{11} + V_2 w_{12}) A + (V_1w_{21} + V_2w_{22}) B + (V_1w_{31} + V_2w_{32}) M$ ………… Equation 4.7

By selection, the coefficients of input variables A, B and M from the general Equation 4.7 are therefore;

$a = V_1w_{11} + V_2w_{12}$,

$b = V_1w_{21} + V_2w_{22}$,

$c = V_1w_{31} + V_2w_{32}$.

In the artificial neural network (ANN) the coefficients (a, b and c) represent the synaptic weights are used to store knowledge (Haykin, 1994). The weights are subjected to adjustments during data training and learning (values of these weights are refined during training and learning) (Jha, 2016). A collection of the neurons is made intelligent by making cooperate actions, thus a pattern of inputs is created to a neural net, processed as a pattern and results as a pattern. The artificial neural network is, therefore, a mathematical model developed based on the phenomenon of error minimizations. ANN learning occurs when the difference between the desired output and ANN output is small. The patterns' error is measured using a performance measurement called mean square error (MSE) or root mean square (RMS). Lower MSE indicates higher learning of the input data set (Aibinu et al., 2015).

Neural network system ease modelling even when the functional relationships between input factors and project outcomes cannot be defined clearly. The model is also able to generate satisfactory solutions with incomplete and previously unseen data (Aibinu et al., 2015). Using the words of Datt (2012:162), neural networks are applicable in virtually every situation in which a relationship between the predictor variables (independents, inputs) and predicted variables (dependents, outputs) exists, even when that relationship is very complex and not easy to articulate in the usual terms of correlations or differences between groups. Previous studies for which neural networks were used in prediction and optimization in construction management include, estimation of cost of some building elements as reinforced concrete frames (Amusan *et al.*, 2013a), cost estimation at design stage to provide Architects and Engineers with alternatives in cost planning (Aibinu et al., 2015). Wang et al. (2012) used ANN to design final construction cost prediction models. Chen and Hartman (2000) used ANN to predict project cost and time overruns to assist construction managers in developing appropriate contingencies.

Artificial Intelligence learning algorithm (especially ANN) as a technique has been in use since the early 1990s for developing feature-based estimating models. ANNs feature-based cost models are non-linear and they eliminate the need to find a good cost estimating relationship that mathematically describes cost as a function of the variables that have the most significant effects on cost (Kim et al., 2004). Also, ANN can model subtle real word relationship between cost and the cost influencing variables even when the nature of these relationships is non-linear or unknown (Aibinu et al., 2015; Elhag and Boussabaine, 2001, 2002; Emsley et al., 2002; Kim et al., 2004; Skitmore and Patchell, 1990). It is therefore considered a better alternative to regression models for cost and duration impact predictions.

4.12.5.2 Adapting artificial neural network (ANN) system for construction duration impact predictions

In a similar mode of adaptation for construction impact assessment in section 4.11.4.1, artificial neural network (ANN) can be adapted into construction duration impact prediction because it is a net thrown at problems which method of solution is unknown (Coelho et al., 2012). Six main characteristics of ANN are (i) they are alternatives to traditional statistical procedures as they offer new approaches to processes that have not been susceptible to conventional computing (Bode, 2000); (ii) learn directly from data using pattern recognition to simulate human learning and make predictions (Stergiou and Siganos, 2016), that is brain equivalent of electrical circuitry (Mittal, 2016). This learning ability gives ANN an advantage in solving complex problems whose analytic or numerical solutions are hard to obtain (Rafiq et al., 2001); (iii) neural network embodies intelligence in the interconnections between physical neurons (Stergiou and Siganos, 2016); (iv) neural networks are good at solving inexact problems, the fuzzier the problem the more likely a neural network gives an optimized solution than a conventional approach **(**Rafiq et al., 2001). (v) it can take as little as an hour to configure a system where a conventional analysis and programming technique could take six months; and (vi) it can accommodate large variables which are multidimensional, non-linear relationships, consisting of multiple inputs (construction project cost and time driving factors' influence) as in this study.

A typical ANN network structure shown in Figure 4.4 consists of a pattern of interconnections between the input nodes (neurons) on the left side to output neurons on the right side. The inputs X_1, X_2 and X_3 (predictor variables) are the ANN inputs. The input neurons which are interconnected to the hidden layer link the hidden neurons that perform the first summation functions and transfer to the output neurons. The final summation is performed in the output neuron resulting in the prediction model.

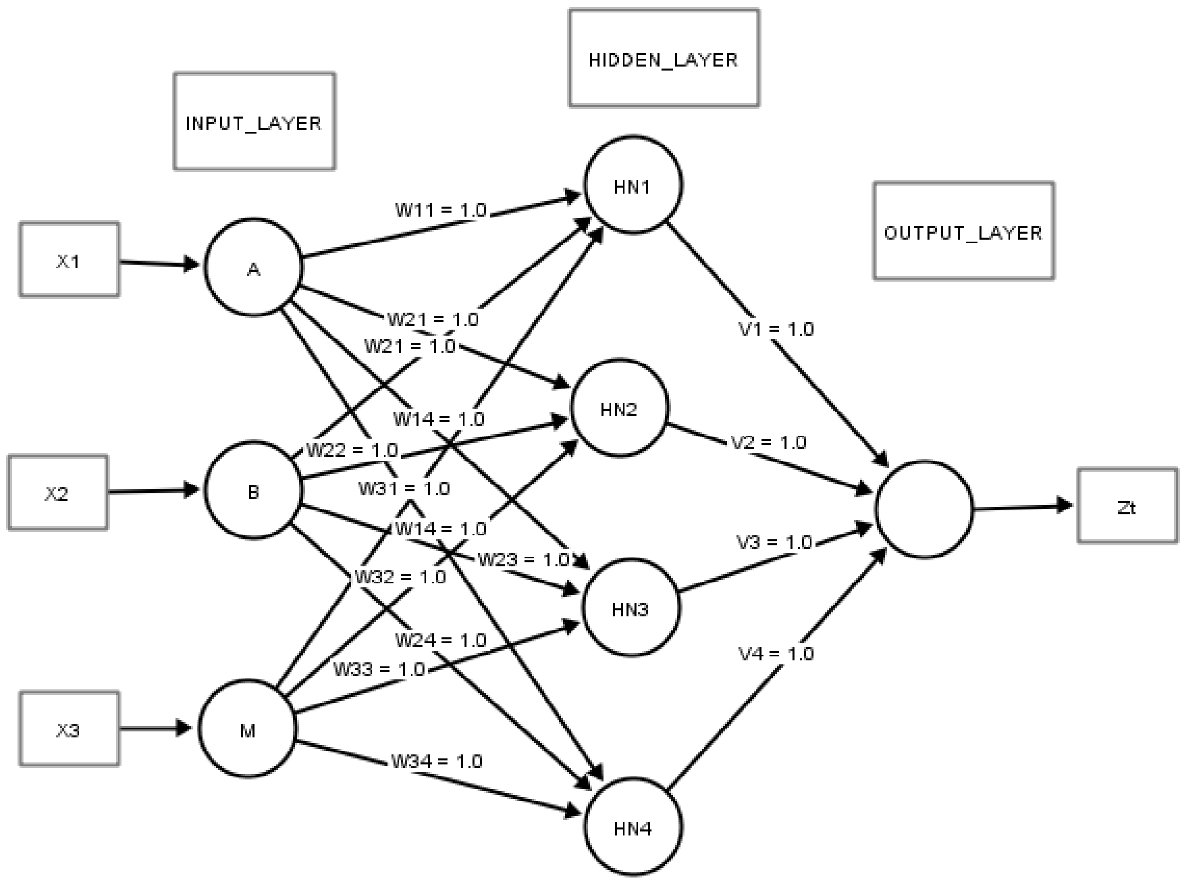


Figure 4.4: Typical artificial neural network (ANN) architecture for duration impact assessment (Source: Kim et al., 2004:1236)

Normally the general multiple linear regression is expressed in the form of Equation 4.8;

$Z_t = \alpha + T_1X_1 + T_2X_2 + T_3X_3 + \ldots + T_nX_n$……………..Equation 4.8

Where; Z_t is the output (dependent variable). In the neural network architecture shown in Figure 4.4, the output a summation of all entering from left to right is expressed with Equation 4.9;

$Z_t = aA + bB + cM$ ……...Equation 4.9

In Equation 4.9, coefficients of the predictor variables A, B and M (input variables shown in Figure 4.4) are a, b, and c. By summation from the entering through hidden to output neurons, Equation 4.9 alternatively can be expressed as;

$Z_t = V_1HN1 + V_2HN2 + V_3HN3 + V_4HN4$……………………………..........Equation 4.10

By expansion and factorization, coefficients of A, B and C can be picked out of Equation 4.10;

$a = V_1W_{11} + V_2W_{12} + V_3W_{13} + V_4W_{14}$,

$b = V_1W_{21} + V_2W_{22} + V_3W_{23} + V_4W_{24}$,

$c = V_1W_{31} + V_2W_{32} + V_3W_{33} + V_4W_{34}$,

Coefficients a, b, and c which represent the synaptic weights in the ANN interconnections are the multiple linear regression model equivalents. They store the ANN knowledge (Haykin, 1994) and are adjustable in the series of iterations, while the network learns, until it is successfully trained to solve a problem presented to it (Jha, 2016). In the developed economies Artificial Intelligence (AI) learning algorithm especially ANN had been in use since the early 1990s for developing feature-based estimating models. ANN, feature-based construction models are non-linear, and they eliminate the need to find a good time estimating relationship that mathematically describes time as a function of the variables that have the most significant effects on the duration of projects (Kim et al., 2004). Also, ANN can model subtle real word relationship between time and the time influencing variables even when the nature of those relationships is unknown. ANN is a better alternative to regression model for predicting cost and time impacts on the initial project targets because the relationship between cost and time drivers' influence is non-linear and distribution types unknown. Another advantage of neural networks is its ability to learn by example; there is no need to devise an algorithm for task performances that is, no need to understand the internal mechanisms of the task (Stergiou and Siganos, 2016).

4.12.6. Artificial neural network impact prediction models development processes adopted in the study

Neural network modelling process involves five aspects; (i) data acquisition analysis and presentation (ii) determination of network architecture (iii) learning process (iv) network training and testing (v) validation of the trained network (Masters, 1993; Ogunlana et al., 2000).

4.12.6.1 Determining the ANN input variables

The significant cost and time driving factors found in the 43 and 49 factors identified from the literature and analysed using group mean factor ranking in sections 5.4 and 5.7 which form the ANN models input variables are shown Table 4.11. The study used 210 and 199 data sets for cost and time respectively in the analysis after further cleanses the data from outliers. The ANN software data inputting format is shown in Table 4.12.

Table 4.11: Significant driving factors as ANN input variables

S/No	Cost	S/No	Time
1	Contract manager's inexperience	**1**	Design errors
2	Payment delays to main contractor	**2**	Cash flow problems
3	Unstable foreign exchange	**3**	Payment delays to main contractor
4	Variation to works	**4**	Inadequate prime cost and provisional sum
5	Fraud/corrupt practices	**5**	Delay in drawing preparations and approval
6	Government's changes in policy and fiscal measures	**6**	Contractors' improper contract knowledge
7	Inadequate prime cost and provisional sum	**7**	Natural disaster such as flood
8	Cash flow problems	**8**	Non-performance of sub-contractors
9	Contract information delay	**9**	Design changes
		10	Variation to works

4.12.6.2 Defining the ANN output variables

Construction project cost performance impacts formed the ANN output data; the ratios of the deviations between the initial contract sums and final costs on the initial contract sums. Similarly, the ANN construction time impacts; ratios of the deviations between the estimated and actual construction durations on the estimated construction durations (Odeyinka, et al., 2012). The cost and time outputs Z_c and Z_t were computed using IBM SPSS Statistics version 24 using Equations 4.11 and 4.12.

Cost performance (Output variables Z_c) = $\frac{Final\ cost - Initial\ contract\ sum}{Initial\ contract\ sum}$… ……………Equation 4.11

Time performance (Output variables Z_t) =

$$\frac{Actual\ construction\ duration - Estimated\ construction\ duration}{Estimated\ construction\ duration}$$

……………………………………………………………………………...Equation 4.12

The cost and time impacts (outputs) values obtained were cleansed from outliers (1.00 and above) together with the input values from cost and duration influence factors were fed into the ANN software using the format shown in Tables 4.12.

Table 4.12: Format for artificial neural network input and output data feeding of the software in model development

Case	Input Variables ($BC/BT_1 \ldots BC/BT_7$)							Output (Cost/time Impact - Z)
	BC/BT	BC/BT	BC/BT	BC/BT	*BC/BT*	…	*BC/BT*	
1.	.	.	.	.	.	.	.	.
2.	.	.	.	.	.	.	.	.
3.	.	.	.	.	.	.	.	.
4.	.	.	.	.	.	.	.	.
5.								
209/198.								

Source: Kaur (2016:522)

4.12.6.3 Data partitioning

The input and output data sets are normally divided into two or three. Squeira (1999) partitioned data set into 60 %, 20% and 20% - training and learning, testing and validation respectively, Jha (2016) partitioned the survey data into 70%, 20% and 10%. Like Gunaydin and Dogan (2004) this research data (209 for cost and 198 for the time) were divided into two subsets in a ratio of 80% and 20% for training and validation or production. There are no acceptable generalized rules to determine the size of the training data for suitable training; however, the training sample should cover all spectrums of data available (Setyawati et al., 2002).

4.12.6.4 Training and testing the ANN learning models

The training set is the largest set and is used by neural networks to learn patterns present in the data (Jha, 2016). This is referred to as data mining, the analytic process for exploring large amounts of data in search of consistent patterns, correlations and/or systematic relationships between variables, and then validates the findings by applying the detected patterns to new subsets of data (StatSoft Inc, 2008). It attempts to examine databases to discover hidden patterns and relationships to find predictive information for improvement. Although it is yet to find extensive application in practice within the construction industry, construction management researchers have started investigating data mining's applicability to different problems. It has been applied to estimating the productivity of construction equipment (Yang et al., 2003), improving construction knowledge management (Yu and Lin, 2006), study of occupational injuries (Cheng et al., 2012) and prediction of the compressive strength of concrete (Cheng et al., 2012).

Training phase requires preparation of the data and adoption of the learning law for the training. Backpropagation neural networks are utilized when a set of inputs are known to match corresponding outputs, but the nature of the relationship is unknown. A network attempts to find a mathematical relationship between the defined inputs and outputs as it is repetitively presented with the data through a supervised training process. Once the networks were performed with an acceptable percentage of error (MPE), they were considered trained and ready to assist in the future generation of cost and time impacts.

The error for all patterns is measured using mean square error (MSE) or root means square (RMS), which is a major performance measurement in ANN learning. Lower MSE indicates higher learning of the set of the input pattern. According to Hola and Schabowicz (2010) the ANN is well trained when:(i) the training error values and the testing error values are similar; (ii) the numbers of epoch are the smallest for the adopted error value; (iii) the correlation coefficient for the data mapping is close to 1 and (iv) the relative training and the testing errors are the smallest or tending to zero. The MSE is used as the criteria for ending the training. This defines the degree of learning of each ANN. The error was calculated concurrently for the training and the test data in the training of each ANN model.

4.12.6.5 Validating the ANN learning models

Adrion, et al. (1982) and Okeefe and Lee (1990) define validation as the determination of the correctness of the concept or theoretical model. Next in step to the model training and learning described by Feng et al. (2006) as critical is testing the ANN models' prediction accuracy using new data set to evaluate the performance (Aibinu et al., 2015; Gunaydin and

Dogan, 2004). In this study, model validation was achieved using new datasets to investigate the fitness of the models conceptualized in Chapter Three. A final check on the performance of the trained network is made using validation set (cases the network had not seen during its training). The performance was primarily measured against the accuracy observed in the prediction set. Confidence analysis of a neural network is used to estimate the variance assuming a normal distribution and a check for the presence of overtraining and thereafter select parameters to be used in minimizing the generalization error (Albino and Garavelli, 1998; Al-Tabtabai et al., 1999; Al-Tabtabai and Alex, 2000). Performance yardsticks of ANN models are, (i) mean absolute percentage error (MAPE), (ii) mean absolute error rate (MAER), (iii) mean square error (MSE) or root mean square (RMS) which errors between the predicted values and actual values in the new sample (Aibinu et al., 2015; Ismail et al., 2011; Marovic et al., 2017). When results are inappropriate, the model may need to be re-specified and redesigned.

4.12.6.6 Use of the Model

Model testing means feeding the network model with new datasets. The model is suitable for use if the results of a test process are acceptable in terms of error margin; the acceptable level of the result of the model can be evaluated based on the value of the correlation between the predicted values and actual values in the new sample as well as the mean square error (MSE). If the result is inappropriate, the model may need to be re-specified and re-designed (Idama, 1999).

In the assessment of cost and time impacts for a new project with the models designed in this study, the user first extracts the values associated with the significant factors described. The input parameters keyed into the model and the network recalled. The network automatically predicts either the cost or time impacts of the project on the initial contract sum or the estimated construction duration.

4.13 Ethical considerations

Researchers and research subjects are protected when a proper ethical protocol is observed in research (Sommer and Sommer, 2002; Wachs, 1990). Ethical concept describes codes and principles which guide human conduct. According to Akogun (2000) ethics is the people's definition of what is good and right or their worldview. Several ethical theories have been traced to philosophers as Plato, Aristotelian ethics, Epicurus, Cynicism, Stoicism and Utilitarianism. The most logical of them is that of the Greek philosopher Plato which claims that the people will act good if they know the rules, while that is true to some extent, many criminal acts are perpetrated even when the actors are aware that such conducts inflicted pains on their party or parties. However, in Hauser (2006), Govrin (2014) and Mikhail's (2011) works on moral psychology, there are strong evidences suggesting that moral judgement is intuitive, accompanied by rapid, automatic and unconscious phychological process. Based on such evidences, a conclusion can be drawn; that morality is innate. That notion explains why children, not yet tutored, hide what they had taken without their parent's knowledge, on sighting an elder. In the same vain, those who may have offered human sacrifice could not have been doing the acts openly, besides that, the victims might have attempted escapes or cried and struggled on sighting death instruments. Such reactions of the victims without doubt pointed to the innate moral faculty and knowledge of the people on whether the acts were good or bad. Historically, human sacrifice though established practice in various cultures purported for the good of all and probably done openly, Carrasco (2013) described the acts as violent, stressing they are fading in modern societies.

While the various theories on ethics cannot be undermined but with a selection of some of their good and morale philosophical thoughts, there is an embodiment of ethical principles which every human ought to use as guide. Jesus' theory a summation of all past, present and future ethics. Though Jesus Christ claimed those killing him did not know what they were doing. Those who killed Jesus Christ had the knowledge of their act, but it was the wrong knowledge. Jesus Christ prayed that prayer only because of His magnanimity, and through that act could His mission on earth be fulfilled. Ordinarily, it is the same man's ethical code that man should seek and find, ask and be given. Therefore, the UCT research ethics which are mandatory for every research candidate were sought for knowledge for sake of compliance and precautions were taken against direct or indirect violations in the conduct of this study. The researcher, though neither questioned the UCT's mode of research ethical principles nor assumed knowledge as an academic staff in another University but asked for reasons informing UCT's ethic committee signature approval which benefits as learnt, cover all involved in the research beginning with the researcher.

Ethical issues permeated every aspect of this research as citing sources, fieldwork with human subjects, construction project cost and duration data collection (See Appendices II and III research participants' consent form and letters of introduction), analysis and interpretations (Holness, 2015). Ethics were therefore at the centre of this study to avoid any false impression and presentations (Clifford et al., 2010). Therefore, it was necessary at the beginning of the fieldwork to obtain ethical clearance from the concerned committee in the University (see Appendix I the ethics committee approval signature form). The research conduct hinges on considerations for honesty, integrity, informed consent, confidentiality, carefulness and right to privacy of the research participants (Bateman, 2012; Steneck, 2006). The wishes and rights of respondents were fully considered and respected; their identities are not disclosed therefore; possible harms were prevented. Participants had the freedom to either volunteer or withdraw from the research without compulsion and undue influence, possible risks were minimized. The identity, privacy and secrecy of organizations involved in the study are not known to any person except the researcher and supervisors.

4.14 Summary of research methodology

Terms as philosophy, epistemology, ontology, axiology and strategy used in classifying the study were defined and explained in the context of the research questions and the inherent assumptions. The chapter discussed the design of data collection instrument, factors considered in determining the study sample size; refinements conducted on the questionnaire from the gains of pilot survey, the purposive sampling method employed in the administrations, collations and analysis of the research participants' responses. Also presented in the chapter is the mean scores compution method for respondents grouped in stakeholder; clients, consultants, main contractors and subcontractors/suppliers. Procedure of conducting componet factor analysis (PCA) tests on the driving factors was discussed. So also, was ways of using one-way between-groups ANOVA with post-hoc test for cost and time variability assessment and one-way repeated measures ANOVA for comparing cost and time impacts among groups of uncomplicated, moderately complex and complex building projects were discussed. The extension of simple correlations between two variables to real life situation of correlating sets of independent variables (factors' influence) and the dependent variables (impacts) applied in the development of multiple linear regressions impact models were discussed. The chapter further discussed checks conducted on the collected data for non-violations of the statistical assumptions required of data employed in the design of multiple linear regression equations. The analysis of modalities for adapting ANN into construction project cost and time performance challenges as alternative to multiple linear regressions and the modelling processes up to the validations and models use were discussed. The Chapter closed with the discussion of the research ethics observed in the study.

CHAPTER FIVE: DATA PRESENTATION, ANALYSIS AND DISCUSSION

5.1 Introduction

The chapter presents the descriptive and inferential statistical data analysis, beginning with the respondents' background details and the surveyed project information. In line with the research objectives and hypotheses, the analysis and test results are presented in the chapter. These comprised the significant cost and time driving factors, construction project cost and time performance data in the locations within the study area. Other data presented in the chapter include a test of cost and time performance differences between largely complex and less complex construction projects and correlations between various project variables. The chapter ends with the discussion of the research results in the light of relevant and existing literature in the construction project performance knowledge area.

5.2 Background details of respondents

The respondents identified using professional and project database, were used in identifying the construction projects studied. It can be seen from Tables 5.1a – 5.1d and 5.4 that 246 completed projects were studied from the data supplied by 246 respondents. The choice of one respondent per project was premised on the fact that site diaries are kept on construction project sites, by representatives of the main contractor and consultants such as the site engineer' and the 'clerk of works' who manage and keep daily records of site operations. Details of respondents' professions and membership of professional associations, grouping of respondents in stakeholder category and industrial experience are presented in the following Tables, 5.1a to 5.1d. As shown in Table 5.1a, the research participants were construction industry professionals, 45.53% are registered builders, 25.21% comprises mechanical, electrical, civil and structural engineers, 21% are architects, and 8% quantity surveyors. It can be seen from Table 5.1b and 5.1d that the respondents are qualified members of their respective professional associations, with satisfactory post-qualification experience, engaged in construction project activities at the time of the survey. Respondents were also employed by the various stakeholders to the construction industry at the time of the study. This is shown in Table 5.1c. Therefore, the information they provided is judged as reliable for use in this study.

Table 5.1a: Respondents' professional background details

Profession	Frequency	Percentage (%)
Builder	112	45.53
Architect	52	21.14
Mechanical & electrical engineer	32	13.01
Civil/structural engineer	30	12.20
Quantity surveyor	20	8.13
Total	**246**	**100%**

Table 5.1b: Respondents' membership of professional association

Professional association	Frequency	Percentage (%)
Member Nigerian Institute of Building	107	43.50
Member Nigerian Society of		

Professional association	Frequency	Percentage (%)
Engineers	55	22.36
Member Nigerian Institute of Architects	52	21.14
Member Nigerian Institute of Quantity Surveyors	18	7.32
Graduate members	14	5.69
Total	**246**	**100%**

Table 5.1c: Respondents' Stakeholder Category

Stakeholder Category	Frequency	Percentage (%)
Main contractor	90	36.59
Project consultants	85	34.55
Client's in-house project team	54	21.95
Sub-contractor	17	6.91
Total	**246**	**100%**

Table 5.1d: Respondents' post-qualification experience

Post Qualification Experience	Frequency	Percentage (%)
Up to 5 years	42	17.07
6-10 years	81	32.93
11-15 years	46	18.70
16-20 years	23	9.35
Over 20 years	54	21.95
Total	**246**	**100%**

5.3 The construction projects surveyed

A total number of 246 completed public projects shown in Tables 5.2 and 5.3 in the study area are distributed to; Adamawa North, Adamawa South, Bauchi State, Gombe and Taraba States 20% (48), 25% (61), 19% (48), 17% (45) and 18% (44) respectively. The highest final construction cost of projects surveyed is ₦303000m while ₦103.80m is the lowest cost. The maximum and minimum delivery periods of construction are 20 and 192 weeks shown in Table 5.3.

Table 5.2: Project locations in the study area

S/No	Location	Frequency	Percentage
1.	Adamawa North	48	19.50
2.	Adamawa South	61	24.80
3.	Bauchi State	47	19.10
4.	Gombe State	46	18.70
5.	Taraba State	44	17.90
	Total	246	100.00

Table 5.3: Range of construction cost and duration of projects surveyed

Final cost and actual construction duration	N	Range	Minimum	Maximum
Final cost (₦m)	246	302,896.20	103.80	303,000.00
Actual Construction Duration (Wks)	246	172.00	20.00	192.00

5.3.1 Project types and locations

Adamawa South in Table 5.4 has the highest concentration of public buildings 25% (61) in the sample. Others are Adamawa North and Bauchi States 19.51% (48) each. Residential buildings, office complexes and school buldings are the prevalent building types in the three states which have the largest concentration of public buildings. The two states with a slightly lower concentration of public buildings, are Gombe 18.29% (45) and Taraba 17.89% (44) which have mostly office complexes and school buildings.

Table 5.4: Cross tabulation of location and project type

Building Type	Location of projects					Total	
	Adamawa North	**Adamawa South**	**Bauchi State**	**Gombe State**	**Taraba State**	**N**	**%**
Residential	9	8	2	3	0	22	8.94
Office Complex	11	21	12	14	9	67	27.34
Industrial Warehouse	4	4	2	2	2	14	5.69
Hotel/Guest House	1	1	2	2	0	6	2.44
Shopping Complex	3	5	4	5	6	23	9.35
School Building	3	7	10	8	14	42	17.07
Tertiary Institution Buildings	6	6	8	4	5	29	11.79
Financial Institution Buildings	9	5	7	4	5	30	12.20
Mosque/Church	1	2	1	2	2	8	3.25
Road construction	1	2	0	1	1	5	2.03
Total	48 (19.51%)	61 (24.80%)	48 (19.51%)	45 (18.29%)	44 (17.89%)	246	100.00

5.3.2 Project location and procurement systems

The three prevalent procurement systems in the study area are management contracting, the traditional contract system, and the cost reimbursement or target cost contract, as shown in Table 5.5; 27% (66), 20% (50) and 15% (37) respectively. The use of those three top procurement systems spread almost equally across locations in the study area, except in Adamawa North where the traditional contract is more in use than any other system of procurement. In the same way, the management contracting system is much more employed in Bauchi and Taraba States than any other systems. All-in service/package deal and Two-tier contract systems were not used in Adamawa North and Bauchi States.

5.3.3 Project type and procurement systems

It can be seen in Table 5.5 that management contracting, the traditional contract system and cost reimbursement top the list of procurement systems and were used to raise four building types; office complexes 27.24% (67), schools 17.07% (42) and financial institutions 12.20% (30) and residential buildings 8.94% (22) in all the states in the study area.

Table 5.5: Cross tabulation of project location and procurement system

Procurement System	Location of projects					Total	
	Adamawa North	**Adamawa South**	**Bauchi State**	**Gombe State**	**Taraba State**	**N**	**%**

Procurement System	Location of projects					Total	
	Adamawa North	Adamawa South	Bauchi State	Gombe State	Taraba State	N	%
Traditional Procurement	17	12	9	5	7	50	20.33
Fixed/Firm Price Contract	6	7	5	9	2	29	11.79
All-in Service/Package Deal	0	3	0	1	1	5	2.03
Cost Reimbursement/Target Cost Contract	7	12	6	7	5	37	15.04
Turnkey	3	6	4	1	6	20	8.13
Two-Tier Contract System	0	2	0	4	2	8	3.25
Management Contracting	9	14	16	11	16	66	26.83
Construction Management	5	3	7	4	0	19	7.72
Boot	1	2	1	3	5	12	4.88
Total	48 (19.51%)	61 (24.80%)	48 (19.51%)	45 (18.29%)	44 (17.89%)	246	100.00

An all-in service or package deal and two-tier systems are the procurement systems used the least, in the study area.

5.4 Assessment of factors influencing construction cost performance of public building projects in the study area

The first part of the first study objective number is to assess the cost performance of public buildings in north eastern Nigeria. A questionnaire survey was carried out to obtain the opinions of construction participants on the 43 identified factors (See Appendix IV, section 3 Questionnaire items BC1 – BC43) from literature and thought to influence construction cost performance. Mean score analysis of the responses from a questionnaire survey of the identified 43 construction cost influencing factors was carried out, and the summary of the analysis is presented in Table 5.6. Two hundred and fifteen (43 x 5 = 215) point Likert items on a 6-point scale were used to measure the factors influencing construction cost in the study area.

It can be seen in Table 5.7 under the total group that the mean score factors (except fluctuation/inflation of material price and changes in specifications) ranged from 2.07 to 2.96. This implies that scores range from very low to a low aggregate influence on construction cost. The two factors found with very low influence on cost performance of public buildings in the study area have scores of 1.65 and 1.54. The top five cost factors found significant in the total mean score group are in Table 5.6:

Table 5.6: Top five factors influencing construction cost performance of public building projects in the study area

S/No	The factor	Mean score
1	Contract manager's inexperience	2.96
2	Payment delays to main contractor	2.85
3	Unstable foreign exchange	2.80
4	Variations to works	2.72
5	Fraud and corrupt practices	2.66

Al-Juwairah (1997) in Saudi Arabia found *Contract manager's inexperience* as one of the topmost construction cost overrun factors. These findings suggest that contract manager's inexperience in the study area could be because of the poor and unscientific system of selection of the prospective project contractor. The abuse of public project procurement system is not unique to the Nigerian and other African nations' construction environments (Achilike and Akuwudike, 2016; Kalubanga et al., 2013; Olatunji, 2007; Osei-Tutu and Owusu-Manu, 2009). In this system, the selected contractors usually have close links with top public servants. In addition, this sytem leads to new sets of contractors entering into the construction contracting market with every change of appointees and chief executives of public organisations, thereby creating situations where the contract managers are new on the job and inexperienced. A further aggravating situation is that because the contractors are changed so frequently, firms who do not have new associates as top public servants will not be guaranteed continuous construction engagements, in which their key technical personnel can learn and consolidate their skills. These contractors were either idle without engagements or laid off when their firms could not secure new contracts after the change of baton. Ayangade et al. (2009) correlated the challenges resulting from influence peddling, sycophancy, and the use of political considerations with the abandonment of government projects, attaching no value to public treasury and high cost of public construction contracts. Ayangade et al. (ibid.) and Olatunji (ibid.) support this discussion by implying a reversal of the Nigerian capital project procurement system to the pre-due process era; this means that the supposed accountability and transparency gains of the Federal Government of Nigeria 2001 Budget Monitoring and Price Intelligence Unit (BMPIU) (Due Process) were unfortunately not sustained.

Payment delay to the main contractor is the next significant factor influencing cost of projects in the study area. This is not surprising, as public organisations are noted for their bureaucratic characteristics that are inclinded to delay, especially **o**n matters regarding funds. This is supported by Alornyeku (2011), Besley and Burgess (2002), Eik-Andresen et al. (2015), Keiser (2011), Liu et al. (2006), Memon et al. (2012b), and Rasul and Roger (2013). Notwithstanding the relevant clauses in the contract conditions, delayed and uncleared contractors' bank cheques are regular challenges with public construction contracts, because of interest on borrowed capital which rises with time. These could be responsible for payment delays to the main contractor in north eastern Nigeria.

Unstable foreign exchange was also found to be a significant cost factor in north eastern Nigeria. In the recent past, the naira exchange rate which changes daily, affects prices of the main construction materials like cement, steel rods, roof coverings and some others that are imported (Okafor, 2016). Reasonable differences between the bills of quantities basic prices are bound to reflect on the differentials between the initial and final contract sums, because of unstable rates of exchange.

Another significant cost factor in north eastern Nigeria, as found in this study, is *variation to works*. Famiyeh el al. (2017), in a similar study in Ghana, found client's intiated variations to the original scope was a siginificant factor. Because clearer appreciation of spaces checked with the departmental operations and equipment usage are more appreciated and have real imact on site than in the drawings, this may be responsible for excessive variations to public projects. In addition, the value-in-use of the construction project becomes clearer to most clients during construction, especially where there were no inputs from the prospective user departments at the design stages. However, revisions approved and effected in such cases increase labour and equipment construction time, which invariably translates to cost increases.

Lastly, *fraud and corrupt practices* were identified as a significant cost factor in north eastern Nigeria. The major business interest of construction contractors is profit maximization, and that could propel the contractors to maximize profits by any justifiable means. Since such interests, which may sometimes be excessive, are hardly checked in public construction contracts, it could incline government officials to make extra money through corrupt practices. Fraudulent contractors and corrupt government officials charged with construction contract awards and payment approvals could be highly tempted financially; the unchecked excesses could contribute to the undue contract cost growths. This is supported by the findings of Kasimu (2012) which shows why fraudulent and corrupt practice is within the top five significant construction cost drivers in the study area. Recently Felter et al. (2018) concluded thus; record of political corruption and inequality in Nigeria have additional contributions to rise of Boko Haram insurgency, analysts say. Despite being the biggest economy in Africa and the home of a wealth of natural resources, Nigeria has one of the poorest populations in Africa. Roughly half of its two hundred million people live on less than $1.90 per day. Poverty is higher in the Muslim-majority northern regions. Oil has played a major role in driving economic inequality across the country. A small number of elites has long maintained a tight hold on oil revenues, and corrupt government ministers have been charged with embezzling tens of billions of dollars from the sector.

5.5 Factors influencing the construction cost performance of public building projects: Stakeholders' perspectives

Based on clients' opinions, some factors influencing construction cost (See Table 5.7) fall into two categories; very low influence and low influence, between 1.59 and 1.96 representing with 6 factors and 37 factors in the second category. The cost driver noted in the clients' perspective is *Unstable foreign exchange (mean score = 2.91)*. As noted in the total group, the client who pays for all inputs to a project feels the challenge of unstable foreign exchange more than any other stakeholders do.

The driving factors in the consultants' group (See Table 5.7) fall into three categories; very low influence with 3 factors, low influence with 39 factors and moderate influence with only 1 factor. The factor of *contract manager's inexperience* has a mean score of 3.18 and is listed as the topmost significant construction cost driver. It is normal for the consultants to see the contract manger's inexperience first because of their high interest in the project quality, cost and schedule objective.

It can be seen in Table 5.7 the factors from the main contractor's perspective, that the mean scores can be categorized into three levels of score, very low influence with 2 factors, low influence with 40 factors and moderate influence with 1 factor. The single factor in the moderate influence category is *Payment delays to main contractor.* Though the factor is next to the first factor in the total group, the main contractor sees payment delays as the main reason for cost overrun. The factor was however, found by Chileshe and Berko (2010), Frimpong et al. (2003) in Ghana, Lee (2008) in Korea and Memon et al. (2012b) in Malaysia, as one of the significant construction costs overrun factors.

It can also be seen in Table 5.7 that factors in the subcontractors' group fall into three categories; 6 factors of very low-cost influence, 34 low cost influence factors and 3 factors of moderate cost influence. The three factors with moderate construction cost influence are *economic insecurity (mean score = 3.35), Unstable foreign exchange 3.18 and Unstable and high interest rate (mean score = 3.00).* The subcontractor expresses the experiences as they relate to the contractual responsibilities. The responsibility for material security at the site is that of the main contractor. The subcontractor receives monies of completed works through the main contractors, and sources materials for work, especially services (electrical and mechanical) which in most cases involve imported items, with their attendant exchange rate.

Table 5.7: Mean scores for factors influencing construction cost performance

S/No	Cost variables	Total	Client	Consultant	Main Contractor	Subcontractor
		Mean	Mean	Mean	Mean	Mean
1.	Contract manager's inexperience	2.96	2.67	3.18	2.92	2.94
2.	Payment delays to main contractor	2.85	2.87	2.68	3.01	2.76
3.	Unstable foreign exchange	2.80	2.91	2.61	2.84	3.18
4.	Variations to works	2.72	2.78	2.74	2.72	2.47
5.	Fraud/corrupt practices	2.66	2.59	2.92	2.53	2.24
6.	Government's changes in policy and fiscal measures	2.65	2.46	2.6	2.80	2.65
7.	Inadequate prime cost and provisional sum	2.64	2.61	2.75	2.61	2.35
8.	Cash flow problems	2.63	2.43	2.49	2.96	2.24
9.	Contract information delay	2.63	2.48	2.76	2.60	2.53
10.	Inadequate project monitoring	2.61	2.43	2.69	2.69	2.35
11.	Lack of co-ordination of project parties	2.59	2.59	2.68	2.58	2.12
12.	Payment delays to sub-contractor and supplier	2.57	2.59	2.64	2.46	2.82
13.	Unstable and high interest rate	2.54	2.65	2.34	2.59	3.00
14.	Non-adherence to contract conditions	2.53	2.09	2.89	2.56	2.00

S/No	Cost variables	Total	Client	Consultant	Main Contractor	Subcontractor
		Mean	Mean	Mean	Mean	Mean
15.	Economic insecurity	2.52	2.44	2.52	2.42	3.35
16.	Contractors' improper contract knowledge	2.52	2.30	2.55	2.73	1.88
17.	Shortage of labour	2.50	2.02	2.45	2.80	2.76
18.	Changes in material specifications	2.49	2.46	2.68	2.32	2.53
19.	Delay in equipment supply	2.49	2.15	2.68	2.51	2.53
20.	Lack of relevant information and details	2.48	2.31	2.4	2.73	2.12
21.	Industrial unrest/strikes	2.46	2.35	2.61	2.52	1.76
22.	Lack of communication between parties	2.46	2.41	2.54	2.60	1.41
23.	Rework due to mistakes	2.44	2.30	2.39	2.62	2.24
24.	Unforeseen site/soil conditions	2.44	2.28	2.59	2.44	2.24
25.	Shortage of equipment	2.44	2.24	2.55	2.50	2.24
26.	Poor cost control system	2.44	2.24	2.51	2.54	2.18
27.	Non-performance of subcontractors	2.43	2.37	2.28	2.66	2.24
28.	Project complexity	2.42	2.09	2.71	2.37	2.35
29.	Delays in the delivery of imported materials	2.42	2.37	2.59	2.28	2.47
30.	Contractor's poor cost/financial management	2.39	2.31	2.38	2.34	2.94
31.	External parties' influence	2.38	1.72	2.65	2.46	2.76
32.	Fuel shortage	2.37	2.07	2.53	2.37	2.47
33.	Poor labour productivity	2.34	2.33	2.4	2.34	2.00
34.	Weak regulations and control	2.34	2.13	2.41	2.36	2.53
35.	Low quality materials	2.26	1.93	2.39	2.36	2.18
36.	Discrepancy/deficiency in contract documents	2.23	2.13	2.42	2.06	2.53
37.	Design errors	2.21	2.07	2.31	2.22	2.12
38.	Contractor's inability to manage risks and uncertainties	2.19	1.96	2.22	2.30	2.12
39.	Conflict between contractual parties	2.14	1.94	2.06	2.42	1.71
40.	Inaccurate cost estimate	2.09	2.09	2.02	2.11	2.24
41.	Design changes	2.07	2.11	1.91	2.27	1.76
42.	Fluctuation/Inflation of price	1.65	1.76	1.39	1.71	2.35
43.	Changes in specifications	1.54	1.59	1.25	1.77	1.59

5.6 Factor analysis test of construction cost factors

The 43 items of the construction cost and time variables were subjected to principal components analysis (PCA) using IBM SPSS statistics version 21. Prior to performing the PCA, the suitability of data for factor analysis was assessed. Inspection of the correlation matrix revealed the presence of many coefficients of 0.3 and above. The Kaiser-Meyer-Olkin value was 0.766 (See Appendix VI), exceeding the recommended value of .6 (Kaiser 1970, 1974) and Bartlett's Test of Sphericity (Bartlett, 1954) reached statistical significance ($p <$ 000), supporting the factorability of the correlation matrix.

The principal components analysis revealed the presence of fourteen components with eigenvalues exceeding 1. The fourteen components explained a cumulative percentage sum of

62.936%. An inspection of the screeplot revealed a clear break after the second component (see Appendix VIII). Since too many components are normally initially extracted, it necessitated an examination of the Screeplot (Tabachnick and Fidell, 2007). Using Ledesma et al. (2015), and Howard's (2016) scree test, and by inspection, the plot reflects a single factor solution based on the inflection point after the first point and a 3-factor solution because there is another inflection point after the third point. It was decided to retain three components for further investigation with Parallel Analysis.

The results of Parallel Analysis however showed five components with eigenvalues exceeding the corresponding criterion values for a randomly generated data matrix of the same size (43 variables × 209 respondents). The five-component solution explained a total of 35.804% of the variance, with Component 1 contributing 16.227% and Component 2 contributing 6.014%, Component 3 contributing 5.622% Component 4 contributing 4.209% and Component 5 contributing 3.732% (See Appendix X) (Pallant, 2010). To aid in the interpretation of these five components, oblimin rotation was performed. The rotated solution revealed the presence of simple structure (Thurstone, 1947), with the five components showing several strong loadings and all variables loading substantially on all the five components. There was a weak negative correlation between the five factors (*r* between -.068 and .282) indicating a complete reduction of the 43 cost factors (See Appendix XI). The interpretation of the components is consistent with the responsibilities of the respective contractual parties as clients, consultants and main contractors.

The 43 construction cost drivers are thus reduced to five factor-components shown in Table 5.8. The components named on the basis and in the order of variable constituent loadings in the Pattern Matrix, Structure Matrix and Communalities coefficients are shown in the Oblimin rotated 5 factor-component solutions (Pallant, 2010) in Table 5.8. The Structure Matrix which is unique to the Oblimin output provides information about the correlation between the variables. Pattern and Structure matrices tables combined are normally presented when the Oblimin rotation is performed (Pallant, 2010; Pett et al., 2003; Spurgeon, 2017; Tabachnick and Fidell, 2007). The communalities output table gives information about how much of the variance in each item is explained. Relatively lower values of the communalities indicate the unfitness of the variable for the component. Values in the Pattern Matrix and Communalities lower than 0.5 and 0.3 respectively indicate that the items or variables or factors do not fit well with the others in a component (Oluseye and Olugbenga, 2018; Pallant, 2010). Variables deleted on that basis are: Contractors' poor cost/financial management, poor cost control systems, lack of relevant information and details, discrepancy/deficiency in contract documents, shortage of materials, Government's changes in policy and fiscal measures, Delay in equipment supply, Delay in equipment supply, External parties' influence, unstable foreign exchange, changes in material specification, weak regulation and control, economic insecurity, unstable and high-interest rate, variation to works, contract manager's inexperience, contractor's inability to manage risks and uncertainties, poor labour productivity, project complexity, lack of communication between parties, non-performance of sub-contractors, conflict between contractual parties, rework due to mistakes, shortage of labour and fraud/corrupt practices. The five-factor component solutions with reference to Table 5.8 are;

Component CFC.1: ***Payments and information supply delays by clients***. The items comprise: *payment delays to subcontractors and suppliers, payment delays to the main contractor, contract information delay, and inadequate prime cost and provisional sum.*

Component CFC.2: *Price galloping and inaccurate estimates*. The factors are: *fluctuations/inflation of prices, and inaccurate cost estimates.*

Component CFC.3: *Design errors by consultants and Cash traps of Clients.* They include:*design changes, changes in specifications, design errors, and cash flow problems.*

Component CFC.4: *The 7-point all-inclusive cost drivers.* The constituent factors are; *lack of co-ordination of project parties, improper contract knowledge by contractors, industrial unrest/strikes, and unseen site/soil conditions, delays in the delivery of imported materials, inadequate project monitoring, and fuel shortage.*

Component CFC.5: *Stakeholders related challenges*. The constituent factor is *non-adherence to contract conditions.*

Component 1, apart from the inadequate prime cost and provisional sum which effect is also delay inclined because of time wasted in resolution, comprises delay encompassing factors. Delays in payments to main contractor, subcontractor and suppliers and contract information delay (clarification of ambiguities, supply of detail drawings, issuance and receipts, letters of approval and documented certifications of previously completed works).

Component 2 comprises of unstable prices of materials and inaccurate estimates of quantities in the bills of quantities rates. Changes in prices of construction materials, tools and machines contribute to high cost differentials between the initial contract sum and final cost especially where mistakes in quantity were made off the project's financial guides. The cost differentials occasioned by the prices, coupled with time wasted in resolving the differences, and agreement of the remeasured works increase the initial contract sum.

Component 3 comprises consultant and client related issues related to changes in materials and component specifications, design errors committed because of lack of comprehensive construction site information to the consultant. Changes are sometimes made where the originally specified materials are not available for purchase and are then omitted items in the designs (Shrestha et al., 2013). Irregular releases of funds from either the client for interim payment cerificates, or the contractor's inability to settle bills promptly, increase cost because of interest that runs on borrowed capital (Gebrehiwet and Luo, 2017).

Component 4 comprises all-inclusive factors because it covers issues bearing on national economy as fuel shortages, clients' lapses in coordinating the activities of all parties at work by ensuring that activities key and dovetail into one another. That principle is achievable where there is a good flow of information among the contractual parties. Also, in the component is the contractors' improper contract knowledge, inefficient and ineffective cost planning and control of operations, poor material and personnel management, lack of adequate storage and security controls. The challenges directly and indirectly result in extra and avoidable construction costs. Construction workers industrial unrest, unforeseen site and underground construction issues in the rocky terrains in most parts of the study area like Adamawa, where extra budgetary spending is eventually taken to bring the work to completion.

Component 5 comprises non-adherence to the stipulations of the contract conditions which could inadvertently be occasioned by bureaucracy in public institutions. Delays in receipts of allocations from headquarters by the supervising ministries, misinterpretations of contract documents and receipt of approvals for previously completed work before further site progresses are in this fifth component. Non-confirmations of verbal instructions to contractors by the consultants within the specified time are also included in this component', which eventually contribute to final cost differentials.

Table 5.8: Cost factors pattern and structure matrix for Principal Component Analysis (PCA) with Oblimin rotation of five factors solutions

Factor	Pattern coefficients					Structure coefficients					Communalities
	CFC 1	CFC 2	CFC 3	CFC 4	CFC 5	CFC 1	CFC 2	CFC 3	CFC 4	CFC 5	
Payment delays to sub-contractor and supplier	.667					.647					.445
Payment delays to main contractor	.646					.657					.454
Contract information delay	.555					.581					.351
Inadequate prime cost and provisional sum	.527					.574					.351
Fluctuation/Inflation of price		.674					.675				.531
Inaccurate cost estimate		.553					.537	.313			.413
Design changes			.750					.706			.556
Changes in specifications		.325	.651				.323	.599			.506
Design errors			.567					.570			.355
Cash flow problems			.507					.555		.440	.346
Lack of co-ordination of project parties				.677					.653		.454
Contractors' improper contract knowledge				.646					.654		.446
Industrial unrest/strikes				.645					.649		.430
Unforeseen site/soil conditions				.636					.620		.427
Delays in the delivery of imported materials				.564					.544	.301	.380
Inadequate project monitoring				.537					.577		.419
Fuel shortage				.505					.526		.346
Non-adherence to contract conditions					.561					.577	.366
Eigenvalues	6.978	2.586	2.417	1.810	1.605						
% Variance	16.227	6.014	5.622	4.209	3.732						
% Cumulative					35.804						

5.7 Assessment of construction time influencing factors in public building projects in the study area

The second part of objective 1 is to assess the time performance of public building projects in north eastern Nigeria. A questionnaire survey was carried out to obtain the opinions of construction participants on the 49 identified factors (See Appendix IV section 4, Questionnaire items BT44 – BT92) from literature and thought to influence construction time performance. A mean ranking analysis of the responses from a questionnaire survey of the identified 49 construction time influencing factors was carried out, and the summary of the analysis is presented in Table 5.9. Two hundred and fourty-five (49 x 5 = 245) point Likert items on a 6-point scale were used to measure the factors influencing construction time in the study area.

It can be seen from the total group scores in Table 5.10 that the factors' mean scores except two, ranged between 2.01 and 2.81. This implies a very low to low aggregate influence on construction time. The factors found with very low influence on time performance of public buildings in the study area have scores of 1.34 and 1.45. They are site accident and force majeure. Five significant construction time factors found in this group are in the following Table 5.9.

Table 5.9: Top five factors influencing construction time performance of public building projects in the study area

S/No	The factor	Mean score
1	Design errors	2.81
2	Cash flow problems	2.72
3	Payment delays to main contractor	2.68
4	Contractors' improper contract knowledge	2.66
5	Delay in drawing preparations and approval	2.63

Al-Momani (2000) in Jordan, Assaf et al. (1995) in Saudi Arabia, Muhwezi et al. (2014) in Uganda, Saleh et al. (2009) in Libya, Sunjka and Jacob (2013) in Nigeria. Wong and Vimonsatit (2012) in Australia, had earlier found *design error* to be one major significant factor that affects construction time influence performance. Assaf et al. (1995) in Saudi Arabia, Famiyeh et al. (2017) in Ghana, Odeyinka and Yusif (1997) in Nigeria, Saleh et al. (2009) in Libya also found cash flow problems as a major construction time performance influence factor. Similar studies by Assaf et al. (1995) in Saudi Arabia, Frimpong et al. (2003) in Ghana, Gebrehiwet and Luo (2017) in Ethiopia, Kikwasi (2012) in Tanzania, Pourrostam and Ismail (2011) in Iran, Sambasivan and Soon (2007) in Malaysia, *found delays in payments to the main contractor* a major factor in increasing construction project time performance.

Project consultants' design error tops the list of factors influencing construction time because conflicting designs from various consultants (architects, structural and services engineers) takes time to resolve most especially where the concerned consultants' offices are located outside north eastern Nigeria like Abuja, Kaduna and Lagos. Clients' cash flow problems which lead to delays of stage payments for previously certified jobs cause work holdups since materials cannot be purchased, wages to workers delayed. The factors eventually elongate the initially set construction programmes because of the unavoidable time extensions normally granted to compensate for time losses.

Contractors' improper contract knowledge, fourth on the significant list reflects in construction activities taking more than the optimum construction durations due to the contractors' inability to anticipate operations and material supply bottlenecks ahead of time. Such prior knowledge enables preparations for adequate precautions either to prevent or reduce loss times in the construction programmes. Consultants and clients' lapses in delaid payments to the main contractors and delays in drawing preparations and receipt of approvals from planning authorities are also part of the top five-time overrun factors. This occurs when cheques are not timeously released or where there are issues of cheques uncleared effects.

5.8 Factors influencing the construction time performance of public building projects: Stakeholders' perspectives

It can be seen from 5.9 that in the client's opinion that construction time influence factors fall in three measurement scales of; very low (3) and low (46). The three factors of very low influence on construction time are, *Site accident (mean score = 1.34), force majeure (mean score = 1.56) and civil commotion/community issues (mean score = 1.90)*. A top factor in the low category is *design error (mean score = 2.73).* The public project construction client as a major stakeholder sees the consultant design error as a major construction project time overrun factor, because as stated earlier, discrepancies in the designs of different consultants take time to resolve before further work can progress.

Construction time influencing factors fall into three scales of measurement, very low (2), low (46) and moderate (1) influence on construction time in the consultants' perspective (See Table 5.9). The two very low influence factors are *site accident (mean score = 1.29) and force majeure (mean score = 1.36).* The single factor on the moderate scale is *natural disaster such as flood (mean score = 3.06).* Sites of gully erosion and flood-prone terrains in Adamawa and Gombe are common in the months of July to September annually, this is attested by construction consultant stakeholders.

In the main contractors' perspective, the factors fall into two scales of measurement: very low (2) and low (47) construction time influence (See Table 5.9). The two factors in the very low scale are, *site accident (mean score = 1.33) and force majeure (mean score = 1.53).* The topmost factor on the low scale is *inadequate prime cost and provisional sum* (mean score = 2.89. Due to frequent construction materials change in price and unstable exchange rate, monies initially set aside for electrical, mechanical services and special equipment fall short of actual purchase price. Time spent to seek for approvals for shortfalls are usually accounted in the construction project time overruns.

The construction time influencing factors in the subcontractors' perspective (See Table 5.10) fall into two scales of measurement, very low (16 factors) and low (33 factors). Two factors tie as the topmost factor in low influence on the construction time scale, they are *cash flow problems* (mean score = 2.94) and *inadequate prime cost and provisional sum* (mean score = 2.94). While the subcontractor only knows much on the areas that affect her business, the evidence of subcontractors has to do with clients' and contractors' cash flow problems and the frequent shortfalls in the subcontractors' and suppliers' areas of regular participation, which have to do with prime cost and provisional sum in the construction projects.

Table 5.10: The factors influencing construction time performance

S/No	Variable	Total	Client	Consultant	Main Contractor	Subcontractor
		Mean	**Mean**	**Mean**	**Mean**	**Mean**
1.	Design errors	2.81	2.73	2.98	2.70	2.88
2.	Cash flow problems	2.72	2.50	2.74	2.79	2.94
3.	Payment delays to main contractor	2.68	2.44	2.89	2.73	2.00
4.	Contractors' improper contract knowledge	2.66	2.31	2.98	2.73	1.69
5.	Delay in drawing preparations and approval	2.63	2.38	2.73	2.66	2.69
6.	Inadequate prime cost and provisional sum	2.62	2.33	2.46	2.89	2.94
7.	Design changes	2.61	2.35	2.90	2.49	2.50
8.	Natural disaster such as flood	2.61	2.29	3.06	2.47	2.00
9.	Variations to works	2.60	2.75	2.64	2.54	2.25
10.	Non-performance of subcontractors	2.59	2.60	2.70	2.63	1.69
11.	Conflict between contractual parties	2.57	2.62	2.68	2.44	2.63
12.	Changes in specifications	2.57	2.52	2.57	2.73	1.88
13.	Industrial unrest/strikes	2.57	2.25	2.70	2.67	2.38
14.	Inadequate planning and scheduling	2.54	2.31	2.30	2.88	2.69
15.	Poor site management and supervision	2.53	2.25	2.85	2.56	1.56
16.	Unforeseen site/soil conditions	2.53	2.23	2.57	2.63	2.69
17.	Poor construction programme management	2.52	2.33	2.42	2.69	2.75
18.	Inclement weather	2.52	2.31	2.74	2.40	2.69
19.	Unclear and inadequate instructions to operators	2.52	2.25	2.61	2.71	1.88
20.	Reworks due to mistakes	2.51	2.58	2.38	2.60	2.56
21.	Delay in building permit approval	2.50	2.46	2.52	2.51	2.44
22.	Contract information delay	2.50	2.15	2.57	2.69	2.19
23.	Poor labour productivity	2.49	2.27	2.33	2.67	3.06
24.	Project complexity	2.49	2.15	2.74	2.60	1.63
25.	Delay in the delivery of imported materials	2.48	2.23	2.63	2.42	2.81
26.	Inadequate project monitoring	2.46	2.29	2.64	2.52	1.69
27.	Obsolete/unsuitable construction equipment	2.45	2.04	2.56	2.72	1.75
28.	Delay in inspection and testing of completed work	2.44	2.40	2.52	2.46	2.00

S/No	Variable	Total Mean	Client Mean	Consultant Mean	Main Contractor Mean	Subcontractor Mean
29.	Client's slowness in decision making	2.44	2.35	2.39	2.56	2.31
30.	Inadequate planning and scheduling	2.44	2.25	2.62	2.42	2.19
31.	Programme/schedule delay	2.43	2.29	2.51	2.46	2.25
32.	Lack of co-ordination of project parties	2.43	2.06	2.58	2.56	2.06
33.	Contractor's inability to manage risks and uncertainty	2.42	2.08	2.49	2.60	2.25
34.	Contract manager's inexperience	2.41	2.12	2.54	2.62	1.63
35.	Client's undue interference	2.41	2.33	2.44	2.46	2.25
36.	Poor project management	2.41	2.19	2.52	2.48	2.06
37.	Shortage of labour	2.41	2.13	2.44	2.58	2.13
38.	Insecurity/insurgency	2.40	2.35	2.51	2.48	1.56
39.	Lack of relevant tools and equipment	2.40	2.19	2.44	2.51	2.25
40.	Lack of communication between parties	2.37	2.46	2.62	2.25	1.50
41.	Fuel shortage	2.37	2.04	2.43	2.53	2.25
42.	Contractor's inexperience	2.36	2.29	2.52	2.36	1.75
43.	Bureaucracy in client's organization	2.35	2.33	2.37	2.35	2.38
44.	Payment delays to sub-contractor supplier	2.28	2.15	2.33	2.39	1.75
45.	Political instability	2.20	2.06	2.14	2.31	2.25
46.	Incomplete technical documentations	2.08	2.08	2.10	2.02	2.31
47.	Civil commotion/community issues	2.01	1.90	2.00	2.17	1.56
48.	Force majeure	1.45	1.56	1.36	1.53	1.13
49.	Site accident	1.34	1.25	1.29	1.33	1.94

5.9 Factor analysis test of construction time factors

The 49 items of the construction time variables were subjected to principal components analysis using IBM SPSS statistics version 21. Prior to performing PCA, the suitability of data for factor analysis was assessed. Inspection of the correlation matrix revealed the presence of many coefficients of 0.3 and above. The Kaiser-Meyer-Olkin value was 0.785 (See Appendix XIII), exceeding the recommended value of .6 (Kaiser 1970, 1974) and Bartlett’s Test of Sphericity (Bartlett, 1954) reached statistical significance ($p < 000$), supporting the factorability of the correlation matrix.

The Principal Components Analysis revealed the presence of eighteen components with eigenvalues exceeding 1. The 18 components explained a cumulative percentage variance of 68.997% (See Appendix XV). Since too many or too few components are normally initially extracted with Kaiser and Scree plot, it necessitated an examination of the screeplot (See Appendix XIV) (Tabachnick and Fidell, 2007). The screeplot revealed an inflection after the first point or a 3-factor solution because there is another inflection point after the third point.

Using Ledesma et al.'s (2015) scree test, it was decided to retain the two components for further investigation with Parallel Analysis. This number of components was adjusted by the result of Parallel Analysis conducted.

In this procedure, the list of eigenvalues provided in the Total Variance Explained table and some additional information from another little statistical program (developed by Marley Watkins, 2000) were used. A link was followed to the additional material site to download a zip file (parallel analysis.zip). This was unzipped to the MonteCarloPA.exe PCA for Parallel Analysis. The programme asked for three pieces of information: the number of variables being analyzed (in this case, 49); the number of participants in the sample (in this case, 198); and the number of replications (100 was specified). It gave a behind-the-scenes calculation to generate 100 sets of random data of the same size as the real data file (49 variables × 198 cases). It calculated the average eigenvalues for these 100 randomly generated samples (See Appendix XVI). The eigenvalue obtained in the PCA were compared with the corresponding value from the random results generated by parallel analysis. Where the values were larger than the criterion value from parallel analysis, the component was retained, and rejected where it was less. The results of Parallel Analysis, however, showed seven components with eigenvalues exceeding the corresponding criterion values for a randomly generated data matrix of the same size (49 variables × 198 respondents). The seven-component solution explained a total of 41.963% of the variance, with Component 1 contributing 18.034% and Component 2 contributing 5.176%, Component 3 contributing 4.688% Component 4 contributing 3.758% and Component 5 contributing 3.691% Component 6 contributing 3.383% Component 7 contributing 3.232% (see Appendix XVII). This approach to identifying the correct number of components to retain has been the most accurate, with both Kaiser's criterion and Cattell's Scree tests tending to either over- or underestimate the number of components (Hubbard & Allen, 1987; Zwick & Velicer, 1986). To aid in the interpretation of these seven components, oblimin rotation was performed. The rotated solution revealed the presence of simple structure (Thurstone, 1947), with the seven components showing several strong loadings and all variables loading substantially on all the components. There was a weak negative correlation between the seven components (r between -.237 and .306) indicating a complete reduction of the 49-time factors (See Appendix XVIII). The interpretation of the components was consistent with the responsibilities of the respective contractual parties as clients, consultants and main contractors.

The 49 construction time drivers are thus reduced to 7 factor-components. The components named on the basis and order of variable constituent loadings in the Pattern Matrix (Pallant, 2010), Structure Matrix and Communalities loadings are shown in the Oblimin rotation Table 5.10. Relatively lower values of the communalities indicate the unfitness of the variable into the component. Such unfitted variables were deleted from the components using the 0.5 and 0.3 minimum coefficients rule, in the pattern and communalities Tables recommended and used in the studies conducted by Oluseye and Olugbenga, 2018; and Pallant, 2010. Like the cost factors counterpart, another 25 construction duration influence factors were found with non-significant influence in the study area. The factors delisted on that basis are: site accident, client's undue interference, delay in drawing preparations and approval, delay in inspection and testing of completed work, inadequate planning and scheduling, obsolete/unsuitable construction equipment, poor project management, unclear and inadequate instructions to operators, programme/schedule delay, inclement weather, poor construction programme management, inadequate prime cost and provisional sum, contract information delay, payment delays to the main contractor, payment delays to sub-contractor and supplier, contract manager's inexperience, changes in specifications, design errors, contractor's inability to manage risks and uncertainties, non-performance of sub-contractors, shortage of labour, unforeseen site/soil conditions, lack of coordination of project parties, inadequate project monitoring and contractors' inadequate contract knowledge. The seven factor-components are discussed with reference to Table 5.11:

Component TFC.1 ***The 3-winged bird of industrial unrest/strikes, delay in the delivery of imported materials and fuel crisis.*** The factors are; *programme/schedule delay, industrial unrest/strikes and fuel shortage.*

Component TFC.2 ***The Boko Haram related factors comprising political-religious instability, civil commotion and community issues.*** The five factors are*; civil commotion/community issues, lack of relevant tools and equipment, political instability, insecurity/insurgency, and force majeure.*

Component TFC.3 ***Client's red-tapism and lack of technical-how.*** The factors are: *bureaucracy in client's organization, client's slowness in decision making, and incomplete technical documentations*.

Component TFC.4 ***Project contractor's draw-back and natural disaster.*** The factors are; *delay in building permits approval, inadequate planning and scheduling, a natural disaster such as a flood, contractor's inexperience, and poor site management and supervision.*

Component TFC.5 ***Client's sole responsibility.*** The factors are*, variations to works, and design changes.*

Component TFC.6 ***Contractor-project complexity and client issues***. The factors are: *cash problems, poor labour productivity, project complexity and lack of communications between parties*

Component TFC.7 ***The trouble-shooter factor.*** The factors are: *rework due to mistakes, and conflict between contractual parties.*

Fuel shortages which have been a regular occurrence in Nigeria affect construction contract programmes as some construction tools and equipment powered with petrol are not normally used during periods of fuel scarcity. This has the same effect with site workers' industrial actions and delays caused by faulty construction programmes grouped in component 1.

Component 2 of the construction time influencing factors comprises insecurity and insurgency, political instability, force majeure, civil commotion/community issues that north eastern Nigeria has been experiencing in the past decade. The component factors have become major construction operation programme disruptions in the study area.

Component 3 has to do with government's unfriendly time consciousness in their operations, contractors' cheques take time for preparations and endorsements. Contractors' files require multiple officers' signatures, evidence of compliances with diverse administrative extant circulars are to be attached. These are miscellaneous delay factors in public construction projects.

Component 4, apart from natural disasters such as floods, and client/consultant delay in securing building permit approval, comprises factors affectomg the main contractor's responsibilities. The main contractor is seen as one who leads every other stakeholder in the success or otherwise of timely delivery of construction projects. The main contractors' lapses in site management and supervision, personnel inexperience, inadequate planning and scheduling reflect much on construction project time overrun, and they are the paramount time overrun factors.

Component 5 consists of the project clients' originations of construction delay issues, continuous re-evaluations, additions and reductions to and from original designs, which add to construction operation durations.

Component 6 comprises factors shared between the contractor, the project peculiarity and client. A cash flow problem could be from the project sponsor (client) and contractor. Where such client-contractor related factors interplay on the contractor's difficulty in matching the project's peculiarity due to complexity, production speeds are bound to reduce which cumulatively sum up in time overrun.

Lastly, factors that are loaded on the seventh component are conflict oriented, as it is quite difficult taking responsibility for whatsoever ends in waste, dishonor or discredits. While defective productions are unacceptable to the consultants they call for reworks, the contractor either shifts blame, accepts reworks reluctantly or waits for a future opportunity to retaliate on extra expenditure from profits already made, the adversarial relationships linger which eventually may end in litigation. The overall effects according to Love et al. (2010) are construction contract delays, for which the only compensating measures are eventual elongations of the construction programme.

Table 5.11: Time factors pattern and structure matrix for Principal Component Analysis (PCA) with Oblimin rotation of seven factor solutions

Factors	Pattern coefficients							Structure coefficients							Communalities
	TFC1	TFC2	TFC3	TFC4	TFC5	TFC6	TFC7	TFC1	TFC2	TFC3	TFC4	TFC5	TFC6	TFC7	
Industrial unrest/strikes	.761							.743							.582
Delay in the delivery of imported materials	.661							.694							.522
Fuel shortage	.636							.651							.468
Civil commotion/community issues		.774							.754						.607
Lack of relevant tools and equipment		.662							.669						.541
Political instability		.638							.652						.479
Insecurity/insurgency		.628							.645						.439
Force majeure		.613							.606						.538
Inclement weather									.338						.267
Bureaucracy in client's organization			.730							.722					.534
Client's slowness in decision making			.602							.620					.453
Incomplete technical documentations	.323		.567					.403		.609					.555
Delay in building permit approval				.653							.640				.444
Inadequate planning and scheduling				.628											.450
Natural disaster such as flood				.596							.575				.393
Contractor's inexperience				.558							.597				.384
Poor site management and supervision				.501							.551				.342
Variation to works					.685							.617			.480
Design changes					.577							.579			.367
Cash flow problems						-.647							-.675		.490

Factors	Pattern coefficients							Structure coefficients							Communalities
	TFC1	**TFC2**	**TFC3**	**TFC4**	**TFC5**	**TFC6**	**TFC7**	**TFC1**	**TFC2**	**TFC3**	**TFC4**	**TFC5**	**TFC6**	**TFC7**	
Poor labour productivity						-.601		.343					-.652		.481
Project complexity						-.597							-.625		.421
Lack of communication between parties						-.540							-.586		.406
Reworks due to mistakes							.584						-.319	.614	.481
Conflict between contractual parties							.541	.357					-.303	.586	.501
							Extraction Sums of Squared Loadings								
Eigenvalues	8.837	2.536	2.297	1.841	1.808	1.658	1.584								
% Variance	18.034	5.176	4.688	3.758	3.691	3.383	3.232								
% Cumulative							41.963								

5.10 Variability between initial contract sum, final account, estimated construction and actual duration in the study area

Objective number two of this research is to determine the cost and time performance of selected public building projects in the study area. Questionnaire items set to achieve the objective are in Appendix IV section 2, questionnaire items B7 – B12; project initial contract sum, final account, estimated and actual construction durations. As described in Chapter Four, section 4.11.4.1, a one-way between-groups ANOVA with post-hoc tests were conducted on the field data (See Appendix V) using IBM SPSS statistics version 21 for investigating the construction project cost and time performance or variability between the initial contract sum and final cost as well as between estimated and actual construction durations in the study area.

5.10.1 Levene's Test of homogeneity of variances

The homogeneity of variances test results is shown in Table 5.12, the *p*-values for cost and time overruns are $.012 < .05$ and $.001 < .05$ respectively, indicating violations of the homogeneity of variance rule. In this study the group similarity ratio using the returned questionnaire (69/46 = 1.50) or using the returned questionnaire less the invalid number (61/44 = 1.39). Because the computed group similarity ratio ranged between 1.39 and 1.50 that violation is not significant and poses no challenge to the progress of data analysis.

Table 5.12: Test of Homogeneity of Variances

	Levene Statistic	df1	df2	Sig.
Percentage cost overrun	3.309	4	241	.012
Percentage time overrun	4.681	4	241	.001

5.10.2 Analysis of variances (ANOVA) in cost and time overrun means between groups

In Table 5.13, there is a statistically significant difference at the $p > .05$ level in the five groups: $F (4, 241) = 1.75$, $p = 0.140$ for cost and $F (4, 241) = 2.40$, $p = 0.051$ for time. The Sig. values (ANOVA) are $.140 > 0.05$ between groups for cost overrun and $.051 > 0.05$ between groups for time overrun indicating statistically significance difference between groups. What the p-values do not indicate is the degree to which the variables (overruns and the groups) are associated. With large samples, even very small differences between groups can become statistically significant. The difference has no practical or theoretical significance.

Table 5.13: ANOVA between groups (locations) for percentage cost and time overrun in the study area

		Sum of Squares	df	Mean Square	F	Sig.
Percentage cost overrun	Between Groups	27252.939	4	6813.235	1.747	.140
	Within Groups	939873.893	241	3899.892		
	Total	967126.833	245			
Percentage time overrun	Between Groups	43994.912	4	10998.728	2.395	.051
	Within Groups	1106659.103	241	4591.946		

		Sum of Squares	df	Mean Square	F	Sig.
Percentage cost overrun	Between Groups	27252.939	4	6813.235	1.747	.140
	Within Groups	939873.893	241	3899.892		
	Total	967126.833	245			
Percentage time overrun	Between Groups	43994.912	4	10998.728	2.395	.051
	Within Groups	1106659.103	241	4591.946		
	Total	1150654.015	245			

5.10.3 Mean percentage cost and time overruns

In Table 5.14 the average construction cost overrun percentage in the study area is 48.56 percent. Mean cost overrun in the locations (groups) are Adamawa North 33%, Adamawa South 61%, Bauchi State 42%, Gombe State 58% and Taraba State 46%. The percentage of time overrun across the study area was found as 55%. Percentage time overrun in the various locations (groups) within the study area; Adamawa North 54%, Adamawa South 68%, Bauchi State 33%, Gombe State 70% and Taraba State 48%.

The results in Table 5.14 show that the 61% and 68% construction cost and time overrun percentages are higher in Adamawa South than in any other location within the study area. The statistics are lowest in Bauchi state with 42 and 33% for cost and time respectively. Pallant's (2010) assertion that the stistical significance difference between the zones has no practical or theoretical significance may not be very true in the case of north eastern Nigeria. Because, the mean cost and time performances differentials across the study area are suggestive of the impacts on construction business by the closeness and accessibility of the study area to three main marketing and commercial city centres of Onitsha, Kano and Lagos sea port. While Bauchi is closer to the three cities in by road, Yola in the central axis of Adamawa South is father towards the East. Local and imported construction materials as well as labour supply are therefore possibly better enhanced than in any other states in the zone that are more distant. Cost and time performances in Taraba and Gombe states follow closely in that pattern. The cost and time overrun means which are 58 and 70% rise above those of Bauchi a little, this is because Gombe is further away from Bauchi state on the east. Taraba's closeness to Onitsha and Jos in Plateau helps in the relative ease of materials and equipment sourcing, a possible reason why the cost and overrun means of 46% and 48% are lower than those of Adamawa South.

Table 5.14: Description of percentage cost and time variability per location in the study area

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Percentage cost overrun	Adamawa North	49	33.1534	41.48272	5.92610	21.2382	45.0687	-16.67	200.00
	Adamawa South	61	60.9137	71.90546	9.20655	42.4979	79.3296	-100.00	368.75
	Bauchi State	47	42.2005	46.87522	6.83745	28.4374	55.9635	-16.11	206.67

	Gombe State	45	58.0422	85.61057	12.76207	32.3219	83.7624	-20.00	439.39
	Taraba State	44	45.6765	53.59025	8.07903	29.3836	61.9694	-1.82	256.41
	Total	246	48.5583	62.82879	4.00582	40.6681	56.4485	-100.00	439.39
Percentage time overrun	Adamawa North	49	54.3311	55.71928	7.95990	38.3267	70.3356	-25.00	300.00
	Adamawa South	61	67.7019	86.44641	11.06833	45.5619	89.8418	-33.33	500.00
	Bauchi State	47	33.2734	32.02045	4.67066	23.8719	42.6750	-26.67	128.57
	Gombe State	45	69.6285	85.87006	12.80075	43.8303	95.4267	-25.00	400.00
	Taraba State	44	47.7233	56.57922	8.52964	30.5217	64.9250	-50.00	237.50
	Total	246	55.2398	68.53136	4.36940	46.6335	63.8462	-50.00	500.00

5.10.4 Multiple comparisons of cost and time overruns within groups

It can be seen from Table 5.15 (multiple comparisons) that the sig. values are all above 0.05. Theses indicate acceptance of the null hypotheses in both cost and time overrun means; that there are no significant differences in cost and time overruns among locations in the study area.

Table 5.15: Multiple comparisons of percentage cost and time overruns among locations in the study area

Dependent Variable	(I) Location of projects	(J) Location of projects	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Percentage cost overrun	Adamawa North	Adamawa South	-27.76029	11.98008	.143	-60.6880	5.1675
		Bauchi State	-9.04704	12.75014	.954	-44.0913	25.9973
		Gombe State	-24.88873	12.89395	.304	-60.3283	10.5508
		Taraba State	-12.52307	12.97010	.870	-48.1719	23.1258
	Adamawa South	Adamawa North	27.76029	11.98008	.143	-5.1675	60.6880
		Bauchi State	18.71325	12.12061	.535	-14.6007	52.0272
		Gombe State	2.87157	12.27179	.999	-30.8580	36.6011
		Taraba State	15.23722	12.35178	.732	-18.7122	49.1866
	Bauchi State	Adamawa North	9.04704	12.75014	.954	-25.9973	44.0913
		Adamawa South	-18.71325	12.12061	.535	-52.0272	14.6007
		Gombe State	-15.84169	13.02462	.742	-51.6404	19.9570
		Taraba State	-3.47603	13.10001	.999	-39.4820	32.5299
	Gombe State	Adamawa North	24.88873	12.89395	.304	-10.5508	60.3283
		Adamawa South	-2.87157	12.27179	.999	-36.6011	30.8580
		Bauchi State	15.84169	13.02462	.742	-19.9570	51.6404
		Taraba State	12.36566	13.24002	.883	-24.0251	48.7564
	Taraba State	Adamawa North	12.52307	12.97010	.870	-23.1258	48.1719
		Adamawa South	-15.23722	12.35178	.732	-49.1866	18.7122
		Bauchi State	3.47603	13.10001	.999	-32.5299	39.4820
		Gombe State	-12.36566	13.24002	.883	-48.7564	24.0251

Percentage time overrun	Adamawa North	Adamawa South	-13.37074	12.99965	.842	-49.1008	22.3594
		Bauchi State	21.05770	13.83525	.549	-16.9691	59.0845
		Gombe State	-15.29737	13.99130	.810	-53.7530	23.1583
		Taraba State	6.60782	14.07393	.990	-32.0750	45.2906
	Adamawa South	Adamawa North	13.37074	12.99965	.842	-22.3594	49.1008
		Bauchi State	34.42844	13.15214	.070	-1.7208	70.5776
		Gombe State	-1.92663	13.31620	1.000	-38.5267	34.6735
		Taraba State	19.97857	13.40299	.570	-16.8601	56.8173
	Bauchi State	Adamawa North	-21.05770	13.83525	.549	-59.0845	16.9691
		Adamawa South	-34.42844	13.15214	.070	-70.5776	1.7208
		Gombe State	-36.35506	14.13309	.079	-75.2005	2.4903
		Taraba State	-14.44987	14.21490	.848	-53.5201	24.6204
	Gombe State	Adamawa North	15.29737	13.99130	.810	-23.1583	53.7530
		Adamawa South	1.92663	13.31620	1.000	-34.6735	38.5267
		Bauchi State	36.35506	14.13309	.079	-2.4903	75.2005
		Taraba State	21.90519	14.36683	.547	-17.5826	61.3930
	Taraba State	Adamawa North	-6.60782	14.07393	.990	-45.2906	32.0750
		Adamawa South	-19.97857	13.40299	.570	-56.8173	16.8601
		Bauchi State	14.44987	14.21490	.848	-24.6204	53.5201
		Gombe State	-21.90519	14.36683	.547	-61.3930	17.5826

5.10.5 Effect size

Eta squared, an effect size statistic is computed from the information provided in the ANOVA table using the Eta squared formula;

Eta squared = Sum of squares between groups/Total sum of square. (Kondo-Brown and Fukuda, 2008)

Cost overrun = 27252.939/967126.833
= 0.03
Time overrun = 43994.912/1150654.015
= 0.04

The effect size, calculated using eta squared, were 0.03 and 0.04 for cost and time overrun respectively. Using Cohen's (1988) classifications (0.01 small effect, 0.06 medium effect and 0.14 large effect) the computed values in both cases (cost and time) are of small effect, the sig values supported the acceptance of the null hypothesis. There are no differences in the overrun means between the groups. Recall in Chapter Four section 4.11.3.2 much consideration in one-way between-groups ANOVA with post-hoc test is given to the test power to correctly identify if truly difference exist between the groups. This is because the power test analysis gives an indication of how much confidence should be reposed in the results especially where the null hypothesis was not rejected. The higher the power, the more confident that there is no real difference between the groups. Though both values of Eta squared are small and the null hypothesis is rejected, it can be concluded that there are differences between the group means but a low-test power (Cohen, 1988).

The implications of the above findings (0.03 and 0.04 effect size) of cost and time overrun is that the strength of the relationships between the dependent variables (cost and time) and the independent variables (Adamawa North, Adamawa South, Bauchi State, Gombe State and Taraba State) is weak.

5.10.6 Results of the one-way between-groups ANOVA with post-hoc tests

A one-way between-groups analysis of variance was conducted to explore the percentage cost and time overrun means surveyed in the study centre. The study area was divided into five groups or locations (Group 1-Adamawa North; Group 2-Adamawa South; Group 3-Bauchi State; Group 4-Gombe State and Group 5-Taraba State). Post-hoc comparisons using the Tukey HSD test indicate the mean cost and time overrun scores for the groups as shown in the following Table 5.16.

Table 5.16: Percentage mean cost and time overrun scores within groups in the study area

Group		Mean score			
No	Name	Cost		Time	
		Mean (M) %	Standard Deviation (SD)	Mean (M) %	Standard Deviation (SD)
1	Adamawa North	33.15	41.48	54.33	55.72
2	Adamawa South	60.91	71.91	67.70	86.45
3	Bauchi State	42.20	46.88	33.27	32.02
4	Gombe State	58.04	85.61	69.62	85.87
5	Taraba State	45.68	53.59	47.72	56.58

Based on the computed small effect size for cost and time overruns, it is concluded differences exist between the group means. This implies that within the groups in the study area, cost and time overrun means are not the same. The cost and time factors impact differently on the initial contract sums and estimated contract durations among Adamawa North, Adamawa South, Bauchi State, Gombe State and Taraba State. In other words, the project cost and time factors have different levels of impact on projects in the five groups.

5.10.7 Situating the results of construction cost and time variability in the study area with past studies

Generally, 49% cost overrun was found across the zone while time overrun was 55%. Cost overrun percentage in the study area dropped below that of Achuenu (1999) who found 51.46% cost overrun for public projects in Nigeria. While Aibinu and Jagboro (2002) reported the evasiveness in the trend of cost overrun in the Nigerian construction industry, which they found to be about 18 percent above budgeted limits. Mbamali and Nnorom (2002) also found cost overrun in 24.45%. Omoregie and Radford's (2006) had a lower 14%

minimum average cost overrun across the entire nation (Nigeria). The foregoing indicates improvement in cost performance for year 2002 to 2006 and a rising level of poor cost performance in recent times, when this studies result is compared with Ijigah et al. (2012) who found a cost overrun range of 7.02 to 48.89% in a similar study.

The 49% cost overrun found in this study falls between the global ranges of 40 to 200% reported in Morris and Hough (1987). Portugal's minimum cost overrun was 12% (Moura et al., 2007) and in Malaysia the range of cost overrun for the large project was between 5 to 10% (Memon et al., 2012a). In Korea Lee (2008) estimated cost overruns and the causes in Social Overhead Capital projects, the author found that road and rail projects had a maximum cost overrun of 50%. Oil and gas projects face significant cost overruns, Ernst and Young (2014) reported a cost overrun of 59% and Merrow (2012) also found an average of 33%.

The 55%-time overrun finding of this study is close to that of Ijigah et al.'s (2012), who found a time overrun range 12.50 to 58.33% for the entire nation**.** Olatunji (2008a) found the variant with reference to project construction period as wide as -25 to 300%. Assaf and Al-Hejji (2006) reported between 10% and 30% time overrun in Saudi Arabia for construction projects, which is lower than that of Nigeria.

5.11 Construction project performances comparison among uncomplicated, moderately complex and largely complex building projects in the study area

As stated earlier, currently there is not yet a comprehensive generally accepted definition of complexity (Cooke-Davies et al., 2011) nor of a complex construction project (Mabumbulu, 2016). But based on minimum construction cost of \$250 million (Altshuler and Luberoff, 2003) which aligns with Hass' (2016) second classification of moderately complex projects, though the classes differ in the duration categories. Altshuler and Luberoff aligns with Randolph et al.'s (1987) who is silent on construction duration. Where there is lack of contextual classification from a developing economy like Nigeria, this study adopts that of Altshuler & Luberoff (2003), \$250 million as minimum contract sum with four years minimum duration for large or complex construction project aligning with Randolph et al. (1987). Three classifications of small or uncomplicated (less than \$50,000 bid cost), medium or moderately complicated (\$50,000–\$250,000 bid cost) and large or complex projects (more than \$250,000 bid cost) are therefore established in this study.

5.11.1 Complexity framework used in the study

The translations of Altshuler & Luberoffs (2003) of the United States of America Dollar to the Nigeria Naira in 2018, the year of the study for purpose of classifying the field data was achieved first by converting the 2003 complex construction classification cost bid to total square metre using the [US-DHUDOPDROH] (2005) construction cost per square of \$1077.33/m^2.

A complexity framework was then derived and adopted in this study. \$50 x 10^6 gives 46,411.03m^2 ie [\$50 x 10^6/\$1077.33/m^2] as upper bound for small or uncomplicated and 232,055.17m^2 ie [\$250 x 10^6/\$1077.33/m^2] as the minimum bid cost for large or complex projects. To cater for inflationary rate, consumer price indices (CPIs) which are 45.70 and 14.33 for 2003 and 2018 respectively (National Bureau of Statistics [NBS], 2018) are applied on the Nigerian ₦35, 000.00/m^2 (Windapo, 2005). The conversion process is as follows;

X/35,000.00 = *45.70/14.33*

= *₦111, 618.98/m^2 for year of study 2018*

Thus \$50 x 10^6 = *₦111, 618.98/m^2 x 46411.03m^2*

= *₦5.18billion upper bound for small or uncomplicated construction projects.*

And \$250 x 10^6 = *N111, 618.98/m^2 x 232055.17m^2*

= *₦25.90billion lower bound for large or complex construction projects*.

5.11.2 Cost performance comparison among uncomplicated, moderately complex and largely complex construction projects in the study area

The first part of objective number three of the study is to conduct a comparative assessment of cost performance of some selected uncomplicated, moderately complex and largely complex public building projects in the study area. The surveyed projects (See Appendix V) are grouped into three classes of complexity using the Nigeria 2018 conversion scale shown in 5.11.1 (the fourth column of Appendix XXXIII). The complexity groups together with their cost and time performances data also extracted from the survey data in Appendix V and presented in Table 5.17 were used in the comparstive analysis. The tested hypotheses are;

Null hypothesis (H_0)*: there are no significant cost performance differentials among uncomplicated, moderately complex and complex construction projects in the study area.*

Alternative hypothesis (H_1)*: there are significant cost performance differentials among uncomplicated, moderately complex and complex construction projects in the study area.*

The project complexity cost performance impacts of the selected 206 uncomplicated, 30 moderately complex and 10 complex projects were investigated with IBM SPSS statistics version 21 one-way repeated measures ANOVA discussed in the methodology Chapter Four. The multivariate tests results are presented in the output Tables 5.18, 5.19 and 5.20 and discussed in the subsequent sections.

Table 5.17: Complexity classifications in the cost and time performance

Complexity group (1) Small or uncomplicated projects			**Complexity group (2) Medium or moderately complex projects**			**Complexity group (3) Large or complex projects**		
S/No	**Percentage cost overrun (%)**	**Percentage time overrun (%)**	**S/No**	**Percentage cost overrun (%)**	**Percentage time overrun (%)**	**S/No**	**Percentage cost overrun (%)**	**Percentage time overrun (%)**
1	31.00	500.00	1	56.00	36.00	1	20.00	-20.00
2	2.00	400.00	2	6.00	39.00	2	207.00	20.00
3	10.00	180.00	3	56.00	47.00	3	67.00	47.00
4	186.00	67.00	4	4.00	18.00	4	150.00	127.00

Complexity group (1) Small or uncomplicated projects			Complexity group (2) Medium or moderately complex projects			Complexity group (3) Large or complex projects		
S/No	**Percentage cost overrun (%)**	**Percentage time overrun (%)**	**S/No**	**Percentage cost overrun (%)**	**Percentage time overrun (%)**	**S/No**	**Percentage cost overrun (%)**	**Percentage time overrun (%)**
5	58.00	300.00	5	53.00	121.00	5	58.00	43.00
6	17.00	500.00	6	27.00	121.00	6	103.00	14.00
7	13.00	100.00	7	5.00	116.00	7	91.00	43.00
8	5.00	267.00	8	13.00	121.00	8	87.00	-10.00
9	40.00	12.00	9	38.00	27.00	9	206.00	60.00
10	14.00	129.00	10	14.00	50.00	10	200.00	41.00
11	5.00	67.00	11	14.00	25.00			
12	24.00	120.00	12	96.00	40.00			
13	12.00	167.00	13	9.00	50.00			
14	56.00	213.00	14	50.00	40.00			
15	61.00	69.00	15	48.00	10.00			
16	108.00	25.00	16	36.00	9.00			
17	100.00	200.00	17	10.00	91.00			
18	100.00	25.00	18	65.00	64.00			
19	57.00	65.00	19	1.00	-25.00			
20	50.00	100.00	20	29.00	65.00			
21	4.00	122.00	21	19.00	50.00			
22	53.00	110.00	22	93.00	8.00			
23	4.00	100.00	23	13.00	25.00			
24	10.00	125.00	24	38.00	25.00			
25	12.00	10.00	25	18.00	58.00			
26	167.00	180.00	26	18.00	17.00			
27	37.00	0.00	27	62.00	-50.00			
28	19.00	10.00	28	5.00	8.00			
29	32.00	10.00	29	100.00	15.00			
30	49.00	186.00	30	100.00	7.00			
31	29.00	17.00						
32	-1.00	300.00						
33	47.00	33.00						
34	75.00	50.00						
35	75.00	25.00						
36	28.00	50.00						
37	50.00	33.00						
38	72.00	83.00						
39	24.00	33.00						
40	67.00	67.00						
41	22.00	67.00						
42	7.00	50.00						
43	16.00	50.00						
44	179.00	33.00						
45	80.00	100.00						
46	35.00	20.00						
47	-2.00	8.00						
48	14.00	14.00						
49	80.00	29.00						
50	60.00	129.00						
51	42.00	29.00						
52	26.00	71.00						
53	16.00	43.00						
54	37.00	100.00						
55	21.00	106.00						
56	27.00	50.00						
57	3.00	25.00						

Complexity group (1) Small or uncomplicated projects			Complexity group (2) Medium or moderately complex projects			Complexity group (3) Large or complex projects		
S/No	**Percentage cost overrun (%)**	**Percentage time overrun (%)**	**S/No**	**Percentage cost overrun (%)**	**Percentage time overrun (%)**	**S/No**	**Percentage cost overrun (%)**	**Percentage time overrun (%)**
58	167.00	13.00						
59	167.00	25.00						
60	47.00	38.00						
61	33.00	100.00						
62	40.00	25.00						
63	49.00	50.00						
64	36.00	238.00						
65	40.00	38.00						
66	147.00	38.00						
67	118.00	2.00						
68	30.00	43.00						
69	32.00	22.00						
70	8.00	78.00						
71	71.00	100.00						
72	43.00	44.00						
73	19.00	89.00						
74	14.00	22.00						
75	29.00	11.00						
76	26.00	11.00						
77	13.00	22.00						
78	15.00	33.00						
79	8.00	11.00						
80	4.00	33.00						
81	24.00	11.00						
82	12.00	33.00						
83	11.00	22.00						
84	24.00	79.00						
85	4.00	100.00						
86	4.00	140.00						
87	25.00	38.00						
88	13.00	50.00						
89	36.00	38.00						
90	26.00	80.00						
91	39.00	20.00						
92	11.00	50.00						
93	67.00	80.00						
94	23.00	63.00						
95	23.00	210.00						
96	20.00	20.00						
97	10.00	20.00						
98	70.00	17.00						
99	14.00	-24.00						
100	9.00	19.00						
101	11.00	10.00						
102	62.00	18.00						
103	12.00	64.00						
104	12.00	264.00						
105	300.00	70.00						
106	105.00	9.00						
107	140.00	-20.00						
108	-20.00	155.00						
109	-2.00	67.00						
110	-9.00	33.00						

Complexity group (1) Small or uncomplicated projects			Complexity group (2) Medium or moderately complex projects			Complexity group (3) Large or complex projects		
S/No	**Percentage cost overrun (%)**	**Percentage time overrun (%)**	**S/No**	**Percentage cost overrun (%)**	**Percentage time overrun (%)**	**S/No**	**Percentage cost overrun (%)**	**Percentage time overrun (%)**
111	369.00	9.00						
112	88.00	47.00						
113	9.00	17.00						
114	87.00	70.00						
115	56.00	117.00						
116	98.00	23.00						
117	89.00	100.00						
118	88.00	56.00						
119	83.00	-25.00						
120	16.00	17.00						
121	13.00	8.00						
122	3.00	17.00						
123	242.00	33.00						
124	183.00	33.00						
125	183.00	-13.00						
126	17.00	58.00						
127	10.00	33.00						
128	9.00	33.00						
129	-17.00	33.00						
130	10.00	25.00						
131	6.00	-25.00						
132	5.00	33.00						
133	15.00	50.00						
134	15.00	300.00						
135	34.00	17.00						
136	100.00	8.00						
137	22.00	17.00						
138	-16.00	38.00						
139	100.00	25.00						
140	31.00	13.00						
141	19.00	100.00						
142	19.00	26.00						
143	6.00	8.00						
144	6.00	31.00						
145	20.00	108.00						
146	22.00	46.00						
147	0.00	46.00						
148	-2.00	208.00						
149	12.00	208.00						
150	100.00	46.00						
151	33.00	31.00						
152	14.00	39.00						
153	8.00	29.00						
154	15.00	21.00						
155	5.00	29.00						
156	4.00	58.00						
157	100.00	33.00						
158	250.00	-17.00						
159	75.00	13.00						
160	9.00	-27.00						
161	50.00	40.00						
162	50.00	67.00						
163	98.00	7.00						

Complexity group (1) Small or uncomplicated projects			Complexity group (2) Medium or moderately complex projects			Complexity group (3) Large or complex projects		
S/No	**Percentage cost overrun (%)**	**Percentage time overrun (%)**	**S/No**	**Percentage cost overrun (%)**	**Percentage time overrun (%)**	**S/No**	**Percentage cost overrun (%)**	**Percentage time overrun (%)**
164	53.00	167.00						
165	52.00	17.00						
166	58.00	20.00						
167	33.00	20.00						
168	39.00	33.00						
169	2.00	29.00						
170	48.00	25.00						
171	12.00	19.00						
172	10.00	13.00						
173	4.00	31.00						
174	25.00	25.00						
175	8.00	19.00						
176	4.00	19.00						
177	40.00	6.00						
178	15.00	6.00						
179	45.00	24.00						
180	25.00	47.00						
181	11.00	12.00						
182	-11.00	47.00						
183	40.00	12.00						
184	32.00	12.00						
185	11.00	43.00						
186	33.00	106.00						
187	69.00	39.00						
188	439.00	11.00						
189	15.00	33.00						
190	39.00	17.00						
191	20.00	33.00						
192	14.00	17.00						
193	8.00	1.00						
194	147.00	-33.00						
195	256.00	33.00						
196	103.00	44.00						
197	33.00	33.00						
198	7.00	22.00						
199	15.00	33.00						
200	47.00	33.00						
201	35.00	33.00						
202	83.00	39.00						
203	58.00	44.00						
204	8.00	67.00						
205	200.00	133.00						
206	100.00	25.00						

5.11.3 Results of cost performance comparison between uncomplicated, moderately complex and largely complex building projects in the study area

A one-way measures ANOVA analysis was conducted to compare scores on construction cost overruns among 206 small or uncomplicated, 30 medium or moderately complex and 10 large or complex construction projects. The mean percentages of cost overrun are 37.60% for small or uncomplicated projects, moderately complex 27.20% and 118.9% complex projects

(See Table 5.18). The multivariate tests result of cost performance comparison Table 5.19 show Wilk's Lambda = 0.407, $F(2, 8) = 5.824$. The p $(0.027) < 0.05$, the null hypothesis (H_0) is therefore rejected. There is a statistically significant difference among the three groups of complexities. The multivariate partial eta squared, 0.593, indicates a large effect size of the test power. The implication is that the three groups of complex projects – uncomplicated, moderately complex and largely complex building projects impact differently on the initial contract sums; that means that their overruns on the initial contract sums vary with the level of complexity of the project. Construction projects are sensitive to the levels complexity in them.

Table 5.18: Descriptive statistics of cost performance comparison among uncomplicated, moderately complex and complex projects

			95% Confidence Interval	
Project complexity group	**Mean**	**Std. Error**	**Lower Bound**	**Upper Bound**
1	37.600[a]	17.374	-1.702	76.902
2	27.200[a]	6.910	11.568	42.832
3	118.900[a]	21.376	70.544	167.256

a. Covariates appearing in the model are evaluated at the following values: Project complexity group 1 (Small or uncomplicated projects) = 1.00, Project complexity group 2 (Medium or moderately complex projects) = 2.00, Project complexity group 3 (Large or complex projects) = 3.00.

Table 5.19: Multivariate tests results of cost performance comparison among uncomplicated, moderately complex and largely complex construction projects

Statistical measure	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Pillai's trace	.593	5.824[a]	2.000	8.000	.027	.593
Wilks' lambda	.407	5.824[a]	2.000	8.000	.027	.593
Hotelling's trace	1.456	5.824[a]	2.000	8.000	.027	.593
Roy's largest root	1.456	5.824[a]	2.000	8.000	.027	.593

Each F tests the multivariate effect of Costoverruns. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

5.11.4 Pairwise comparison of cost performance among groups of uncomplicated, moderately complex and largely complex construction projects

Pairwise comparison of cost performance impacts of the three groups of projects are presented in Table 5.20. The sig column gives indication of which pairs of groups have significant differentials in their cost performance. Cost performance differential between uncomplicated (1) and medium or moderately complex (2) projects is not significant because the p-value that is 1.00. The cost performance differentials between small or uncomplicated

(1) and (3) complex projects from the p-value (0.04) < 0.05 are significant. Similarly, the cost performance differential between medium or moderately complex (2) and (3) is also stastically significant, given the p-value (0.019) < 0.05.

Table 5.20: Pairwise comparisons cost performance among uncomplicated, moderately complex and largely complex construction projects

(I) Cost overruns	(J) Cost overruns	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	10.400	19.736	1.000	-47.493	68.293
	3	-81.300*	26.447	.040	-158.878	-3.722
2	1	-10.400	19.736	1.000	-68.293	47.493
	3	-91.700*	25.935	.019	-167.777	-15.623
3	1	81.300*	26.447	.040	3.722	158.878
	2	91.700*	25.935	.019	15.623	167.777

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

*. The mean difference is significant at the .05 level.

5.11.5 Situating cost performance comparison results of uncomplicated, moderately complex and largely complex construction projects within past studies

Jahren and Ashe (1990) and Shrestha et al. (2013) indicated that the higher the number of unit cost items in the tender, the higher the percentage change in contract sum. The authors pointed out that one possible explanation for this was that contracts that have a higher number of unit cost items were supposed to be complex projects (Gidado, 1996; Lee et al., 2006; Lyneis et al., 2001). Nevertheless, Randolph et al. (1987) found that smaller projects had a higher percentage change in project cost. This research result corroborates the 338% and 239% cost overrun for complex projects found by the Nuclear Regulatory Commission (NRC) 1982) and the Energy Information Administration (EIA) (1988). The reasons the organizations adduced are behind their findings: overestimation of benefits (Evans, 2005), errors (Busby and Hughes, 2004), lack of knowledge transfer between projects (Cooper et al. 2002), reworks (Cooper, 1993, Gidado, 1996, Love et al., 1999, 2000, 2002), concealing rework (Ford and Sterman, 2003) and scheduled pressure (Nepal et al., 2006). These findings support the assertion that other factors apart from the complexity challenge are responsible for construction project final cost variability.

5.11.6 Time performance comparison among uncomplicated, moderately complex and largely complex construction projects in the study area

The second part of objective number three of the study is to conduct a comparative assessment of time performance of some selected uncomplicated, moderately complex and largely complex public building projects in the study area. Using the complexity framework shown in 5.11.1 above to classify the surveyed projects. Three classes of complexity emerged from the surveyed projects; 206 small or uncomplicated, 30 medium or moderately complex and 10 complex projects. The classes and their time performance data are presented in Table 5.17. They were analysed on the following hypotheses;

Null hypothesis (H_0): *there are no significant time performance differentials among uncomplicated, moderately complex and complex construction projects in the study area.*

Alternative hypothesis (H_1): *there are significant time performance differentials among uncomplicated, moderately complex and complex construction projects in the study area.*

The complexity impacts on construction project time were investigated with IBM SPSS statistics version 21 one-way repeated measures ANOVA. The multivariate tests results are shown in Tables 5.21, 5.22 and 5.23.

5.11.7 Results of time performance comparison between uncomplicated, moderately complex and largely complex construction projects in the study area

A one-way measures ANOVA analysis was conducted to compare scores on construction cost overruns among 206 small or uncomplicated, 30 medium or moderately complex and 10 largely complex construction projects. The mean percentages of time overruns are 245.50% small or uncomplicated projects, moderately complex 69.60% and 36.50% complex projects (See Table 5.21). The multivariate tests result of time performance comparison Table 5.22 shows; Wilk's Lambda = 0.456, $F(2, 8) = 4.777$. The p (0.043) < 0.05, the null hypothesis (H_0) is therefore rejected. There is a statistically significant difference among the three groups of complexities. The multivariate partial eta squared of 0.544 indicates a large effect size of the test power.

Table 5.21: Descriptive statistics of time performance comparison between uncomplicated, moderately complex and largely complex projects

			95% Confidence Interval	
Project complexity group	**Mean**	**Std. Error**	**Lower Bound**	**Upper Bound**
1	245.500[a]	56.002	118.815	372.185
2	69.600[a]	13.951	38.041	101.159
3	36.500[a]	12.949	7.208	65.792

a. Covariates appearing in the model are evaluated at the following values: Project complexity group 1 (Small or uncomplicated projects) = 1.00, Project complexity group 2 (Medium or moderately complex projects) = 2.00, Project complexity group 3 (Large or complex projects) = 3.00.

Table 5.22: Multivariate tests results of time performance comparison among uncomplicated, moderately complex and largely complex construction projects

	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Pillai's trace	.544	4.777[a]	2.000	8.000	.043	.544
Wilks' lambda	.456	4.777[a]	2.000	8.000	.043	.544
Hotelling's trace	1.194	4.777[a]	2.000	8.000	.043	.544
Roy's largest root	1.194	4.777[a]	2.000	8.000	.043	.544

Each F tests the multivariate effect of Timeoverruns. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

5.11.8 Pairwise comparison of time performance among groups of uncomplicated, moderately complex and largely complex construction projects

Pairwise comparison time performance impacts of the three groups of projects are presented in Table 5.23. The sig column gives an indication of which pairs of groups have significant differentials in their time performance. The time performance differential between small or uncomplicated (1) and medium or moderately complex (2) projects is significant because the p-value (0.029) < 0.05. The time performance differentials between small or uncomplicated (1) and (3) complex projects from the p-value (0.034) < 0.05 is also significant. The time performance differential between medium or moderately complex (2) and (3) is not stastically significant given the p-value (0.572) > 0.05.

Table 5.23: Pairwise comparisons time performance among uncomplicated, moderately complex and largely complex construction projects

(I) Timeoverruns	(J) Timeoverruns	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	2	175.900*	53.750	.029	18.233	333.567
	3	209.000*	65.959	.034	15.522	402.478
2	1	-175.900*	53.750	.029	-333.567	-18.233
	3	33.100	22.513	.527	-32.938	99.138
3	1	-209.000*	65.959	.034	-402.478	-15.522
	2	-33.100	22.513	.527	-99.138	32.938

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Adjustment for multiple comparisons: Bonferroni.

5.11.9 Situating the results of time performance comparison in the context of previous research

The test result shows that there is a significant time overrun difference among small or uncomplicated projects, medium or moderately complex, and large or complex and construction projects. However, between medium and large construction projects, the study found that the time performance differential is not significant. This result is at variance with Al-Ghafly's (1995) who found that that delays occurred more often in medium and large projects in Saudi Arabia public water and sewerage system. The author however reported that the effects of the delay were much more severe in small projects. Al-Ghafly's (1995) findings align with Taylor and Ford (2008) who found complex projects very much susceptible to delays.

5.12 Construction project complexity impacts on cost and time performance in the study area

The complexity framework discussed in section 5.11.1 was used to classify the surveyed projects. The projects were grouped into categories of complexity using the fourth column of Appendix XXXIII which translates the Altshuler and Luberoff's (2003), Randolph et al. (1987) in United States of America Dollar ($million) to the 2018 Nigeria version in the framework. Three complexity groups emerged; small or uncomplicated, medium or moderately complex and large or complex construction projects presented in the survey data in Appendix V. The initial contract sums as well as the estimated construction duration of the identified three groups of complexities were analyzed for the determination of the impacts on the out-turn construction project cost and time.

5.12.1 Project complexity impact on construction cost performance in the study area

The first part of objective number four of the research is to examine the impact of project complexity on cost performance of selected public building projects in the study area. The three groups of complexity classifications; small or uncomplicated, medium or moderately and large or complex construction projects are labelled 1, 2 and 3 respectively. The initial contract sums and cost overruns data from the survey projects in Appendix V are tested on the following hypothesis;

Null hypothesis (H_0)*: Levels of construction project complexities do not impact differently on cost performances.*

Alternative hypothesis (H_1)*: Levels of construction project complexities impact differently on cost performances.*

5.12.2 Results of complexity impacts on cost performance

The differentials in the cost performance from the impacts of complexity (uncomplicated, moderately complex and complex construction projects) was investigated using IBM SPSS statistics version 21 one-way between groups ANOVA with post-hoc test. A total number of 246 completed construction projects were investigated for differentials in the cost and time performance caused by complexities in the projects. The projects are shown in Table 5.17 comprise 206 small or uncomplicated, 30 medium or moderately complex and 10 complex constructions. The results are shown in the SPSS descriptive statistics are presented in Tables 5.24, 5.25 and 5.26.

The mean cost performance scores of the three classes of complexity from Table 5.24 are 47.78, 36.13 and 118.90 for small or uncomplicated, medium or moderately complex and largely complex projects respectively. The p-value from the ANOVA Table 5.25 is less than 0.001 indicating significance difference in cost impact occurring among the three groups of complexity in construction projects, and a rejection of the null hypothesis (H_0). The multiple comparison Table 5.25 shows the difference occurring first between largely complex group (3) and uncomplicated project group (1) and secondly between largely complex group (3) and moderately complex group (2). The results imply that cost performance differentials exist among the groups of complexities of construction. As can be seen in Figure 5.1 the mean cost performance impacts initially fall steadily to the right from uncomplicated group towards the medium or moderately complex projects, before rising steadily upwards in the region of large or complex projects; meaning that moderately complex projects (group 2) less cost performance impacts compared to groups 1 and 3 (small or uncomplicated and largely complex projects).

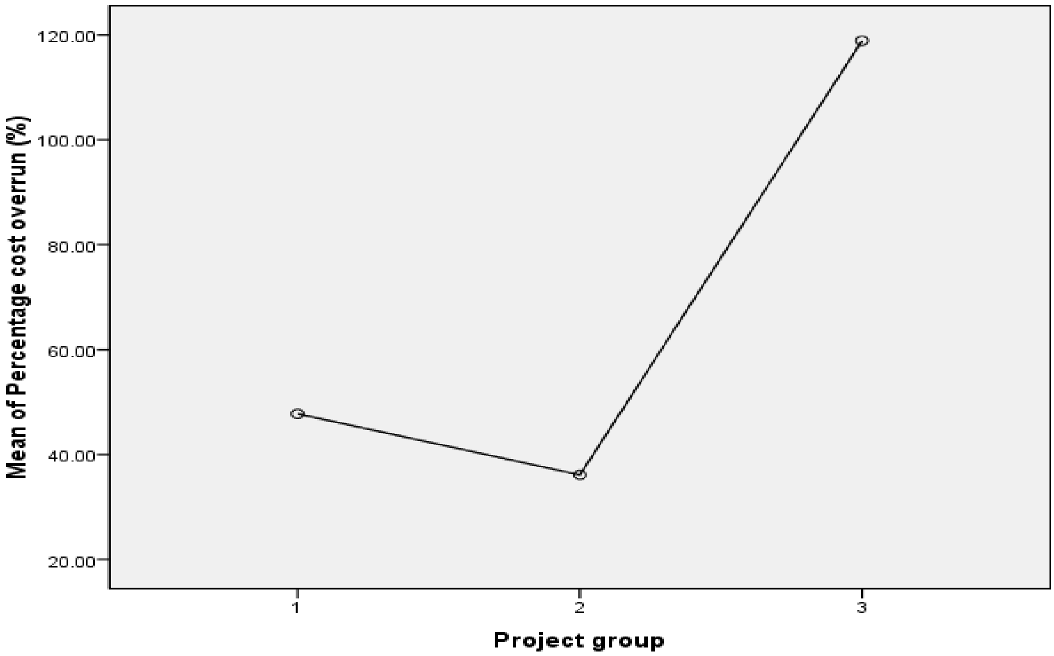


Figure 5.1: Project complexities mean percentage cost overrun

Suggestions that cost overrun rise with increase in project complexity was first drawn from Merrow et al. (1988), Giwa (1988a) and supported in Ugulu and Ikwuogu (2011) and recently in Olaniran et al. 2015. However, Randolph et al. (1987) and Odeck (2004) observed that cost overrun inversely correlated with the size of the project, while Jahren and Ashe (1990) found the opposite.

Table 5.24: Descriptive data for construction projects complexities cost and time performances

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Percentage cost overrun (%)	1	206	47.7816	63.26920	4.40817	39.0904	56.4727	-20.00	439.00
	2	30	36.1333	31.15006	5.68720	24.5017	47.7650	1.00	100.00
	3	10	118.9000	67.59758	21.37623	70.5436	167.2564	20.00	207.00
	Total	246	49.2520	62.07285	3.95762	41.4567	57.0473	-20.00	439.00
Percentage time overrun (%)	1	206	60.7864	78.71042	5.48401	49.9741	71.5987	-33.00	500.00
	2	30	40.9333	41.41042	7.56047	25.4704	56.3962	-50.00	121.00
	3	10	36.5000	40.94780	12.94883	7.2077	65.7923	-20.00	127.00
	Total	246	57.3780	74.22327	4.73230	48.0569	66.6992	-50.00	500.00

5.12.3 Project complexity impact on construction time performance in the study area

The second part of objective number four of the research is to examine the impact of project complexity on time performance of selected public building projects in the study area. Like section 5.12.1, the three groups of complexity classifications; small or uncomplicated, medium or moderately and large or complex construction projects are labelled 1, 2 and 3 respectively. The estimated construction duration and time overrun data from the survey projects in Appendix V are tested on the following hypothesis;

Null hypothesis (H_0): *Levels of construction project complexities do not impact differently on time performances.*

Alternative hypothesis (H_1): *Levels of construction project complexities impact differently on time performances.*

IBM SPSS statistics version 21 one-way between groups ANOVA with post-hoc test was used for the analyses, the results are presented in tables of output, Table 5.24, 5.25 and 5.26 and discussed subsequently.

5.12.4 Results of construction project complexity impact on time performance in the study area

A total number of 246 completed construction projects were investigated for differentials in the cost and time performance caused by complexities of the projects. The projects as shown Table 5.17 above comprise 206 small or uncomplicated, 30 medium or moderately complex and 10 largely complex construction projects. It is shown in the SPSS ANOVA Table 5.25 that the p-value (0.260) > 0.05 indicating no significant difference in the time performance impacts among the three groups of complexity classes. The null hypothesis (H_0) is accepted. As shown in Figure 5.2 the mean of time performance impact falls steadily with largely complex construction projects.

Table 5.25: Analyses of variance (ANOVA) for construction project complexities on cost and time performance.

		Sum of Squares	df	Mean Square	F	Sig.
Percentage cost overrun (%)	Between Groups	54116.837	2	27058.419	7.389	.001
	Within Groups	889877.537	243	3662.047		
	Total	943994.374	245			
Percentage time overrun (%)	Between Groups	14864.873	2	7432.436	1.353	.260
	Within Groups	1334862.969	243	5493.263		
	Total	1349727.841	245			

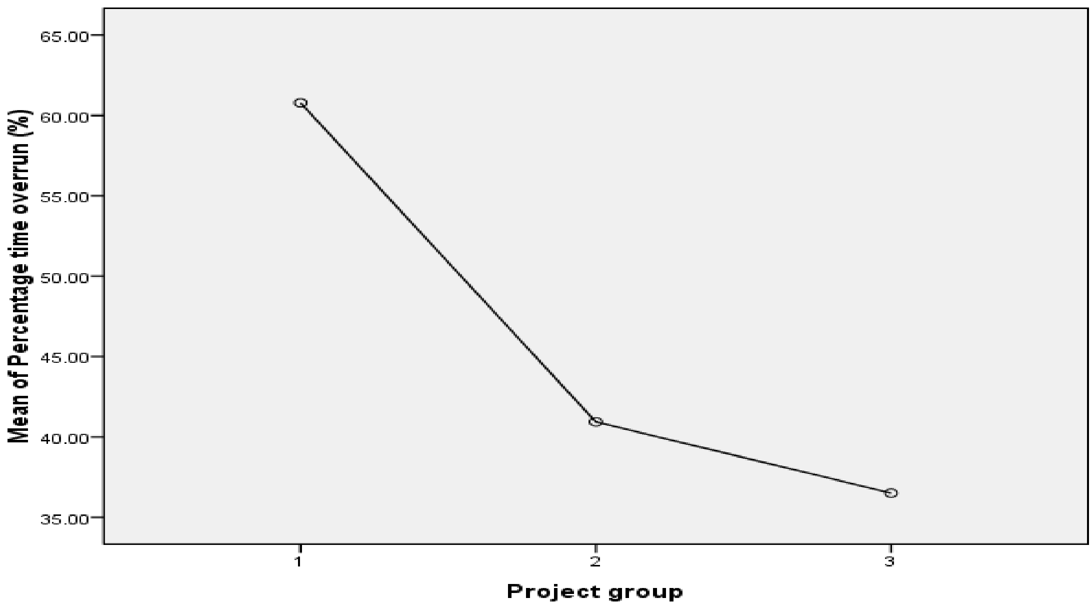


Figure 5.2: Project complexities mean percentage time overrun

Although this finding is contrary to Shah's (2016) findings in Ghana as well as Merrow et al.'s (1988) assertion that schedule slippages rise with project sizes, the implication of this finding is that large or complex construction project originally are designed with long construction programmes which give less challenge of time delays. Less time delays and yielding to better management timewise because of the time buffers and floats built into the construction plans.

5.12.5 Multiple comparison of construction project complexity impacts on cost and time performance in the study area

Comparison of construction project complexity impact on cost and time performances is achieved by considering the sig value (probability) that guides the decision of statistical inference drawn. In Table 5.26 the p-value (0.587) > 0.05 indicates a no statistically significant difference in the complexity impact on the mean cost scores between small or uncomplicated and medium or moderately complex construction projects, an acceptance of the null hypothesis (H_0), in other words, no significant difference between the means. Decision on the difference between the complexity impacts on the mean cost performance between small or uncomplicated and large or complex construction projects is based on the sig value (0.001) < 0.05 which is significant, that is, the null hypothesis (H_0) is rejected. Similarly, there is a statistically significant difference in the complexity impact on the mean cost performance between medium or moderately complex and large or complex projects because of the sig value (0.001) < 0.05 a rejection of the null hypothesis (H_0).

In the same vein, in Table 5.26 there are no statistically significant differences in the project complexity impact on the mean of time performance across the three groups of small or uncomplicated, medium or moderately complex and large or complex projects because the sig values (0.358, 0.570 and 0.985) are all above 0.05 ie acceptance of the null hypothesis (H_0). That there is no statistically significant difference in the project complexity impact on the mean of time performance across the three groups of small or uncomplicated, medium or moderately complex and large or complex projects, suggests that the three groups of projects have the same impact, on Programme of work. The implication of this result is that construction planners have no need to place special consideration to any of the three levels of complexity in construction activities scheduling. Moreover, it implies that complexity is not the only determinant of time overrun in the construction projects. It therefore suggests the existence of other causes of time overruns on construction projects.

Table 5.26: Multiple comparison of cost and time complexities performance impacts

Dependent Variable	(I) Project group	(J) Project group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Percentage cost overrun (%)	1	2	11.64822	11.82562	.587	-16.2385	39.5350
		3	-71.11845*	19.59545	.001	-117.3278	-24.9091
	2	1	-11.64822	11.82562	.587	-39.5350	16.2385
		3	-82.76667*	22.09690	.001	-134.8748	-30.6585
	3	1	71.11845*	19.59545	.001	24.9091	117.3278
		2	82.76667*	22.09690	.001	30.6585	134.8748
Percentage time overrun (%)	1	2	19.85307	14.48361	.358	-14.3017	54.0078
		3	24.28641	23.99985	.570	-32.3092	80.8820
	2	1	-19.85307	14.48361	.358	-54.0078	14.3017
		3	4.43333	27.06354	.985	-59.3870	68.2536
	3	1	-24.28641	23.99985	.570	-80.8820	32.3092
		2	-4.43333	27.06354	.985	-68.2536	59.3870

The results also, show that the difference in cost overruns impacted by the complexity and non-complexity of construction projects is statistically significant, but statistically insignificant between small or uncomplicated and medium or moderately complex construction projects. The time overrun differential among all categories of complexity in construction projects is not staticsally significant. These are supposedly based on the criteria that small or uncomplicated projects using the contract values that are by implication low, are sensitive to further additions to the cost figures. Larger contracts could have cost overruns that are high when compared with overruns from smaller projects but compared to their own initial cost budgets may not be regarded as high. Also drawn from the time performance result is that time management consciousness, construction programme design techniques among construction operations planners and managers for small, medium and complex projects is the same, there are no exceptions for project complexity in the study area.

5.13 Models for assessing the impacts of cost and time influencing factors on cost and time performance of public building projects in the study area

The fifth objective of the study is to develop models for assessing the impacts of cost and time influencing factors on the performance of public building projects in the study area. Two types of models were developed first are the multiple linear regressions cost and time impacts the traditional approach and the alternatives; artificial neural network impact models. The development of the MLR and ANN prediction models involved the following stages of analysis: Identification of the nine and ten significant cost and time factors, using the Pareto rule of 80/20% as discussed in Chapter Four. The significant factors' cost and time influence and as well as impacts discussed also in Chapter Four sections 4.8.2.1 and 4.8.2.2 were taken for models' input and output variables. These were used in the development of mathematical equations and neural network models for assessing overruns on initial contract sums and estimated construction durations.

Mean score analyses of the responses from a questionnaire survey of the identified 43 construction cost and 49-time influencing factors were conducted, and the summary of the analysis are presented in Tables 5.7 and 5.10 in sections 5.4 and 5.7 of this Chapter. Using Pareto rule of 80/20, the top 20% of the 43 cost influencing factors yielded nine significant cost influencing factors for first nine and ten factors for the cost time influencing factors (Grosfeld-Nir et al., 2007; Robert, 1987; Svenssson and Wood, 2006). The cost factors; contract manager's inexperience, payment delay to main contractor, unstable foreign exchange, variations to works, fraud/corrupt practices, government's change in policy and fiscal measures, inadequate prime cost and provisional sum, cash flow problems, contract information delay. And time factors design errors, cash flow problems, payment delay to main contractor, contractor's inadequate contract knowledge, delay in drawing preparations and approval, inadequate prime cost and provisional sum, design changes, natural disaster such as flood, variations to works and non-performance of subcontractors were taken forward as independent variables for the development of the models.

To determine the dependent variables for modelling purpose, the deviations between the contract sum and final cost were computed from the collected data. After removing the outliers, a total of 209 and 198 datasets for cost and time respectively were obtained from the 246 cases, and these were used as variables for modelling purpose. The survey data was divided into two sets of 80% (168) and 20% (41) for variables 159 which is 80% and 39 which is 20% for the time variables (Amusan, 2011). The first category of datasets 168 and 159 (See Appendices XX and XXI) were used for model developments in the Multiple Linear Regression and Neural Networks training. The second category of datasets 41 and 39 (Appendices XXII and XXIII) were used in validating the developed models in Chapter Six. Regression models are built based on the magnitude of R-squared statistic and the Sig value displayed in the SPSS ANOVA output tables from test results of the relationships (correlations) between dependent (impact) and sets of independent variables (significant factors' influence). The correlation tests for the relationship between cost and time impacts and the significant factors' influence are conducted in the following sub-sections.

5.13.1 Relationships between impacts and influence of the driving factors

The main research question, as stated earlier, is focused on the relationship between cost and time impacts and the influence of the driving factors. This relationship can be used to develop cost and duration impact assessment models within a certain confidence level. As the emergent research hypotheses are tested, the R-squared and sig values from the results of the correlation test (between the multiple independent variables —inputs— and the dependent variable —outputs) indicate the strength of the relationship. They also give an indication of whether to proceed with the prediction model development. Thus:

Null hypothesis (H_0): *There is no significant direct relationship between the influence of construction cost-driving factors and the cost impact (cost overrun) in the study area*

Alternative hypothesis (H_1): *There is a significant direct relationship between the influence of the construction cost-driving factors and the cost impact (cost overrun) in the study area.*

Null hypothesis (H_0): *There is no significant direct relationship between the influence of construction time-driving factors and duration impact (time overrun) in the study area.*

Null hypothesis (H_1): *There is a significant direct relationship between the influence of construction time-driving factors and duration impact (time overrun) in the study area.*

5.13.1.1 Results of test for correlation test between cost impact and influence of cost drivers

In Table 5.27 the p-value 0.065 > 0.05, which is not significant, points towards acceptance of the null hypothesis (H_0). This implies no significant correlation between cost impact (cost overrun) and influence of the driving factors, though the correlation (R = 0.308) and (R Square or Coefficient of determination = 0.095) are positive (see Table 5.28) indicating a direct proportional relationship. The coefficient of determination translates to 9.50% of cost overrun explained by influence of the driving factors (independent variables). Notwithstanding, the data certifies all other basic assumptions of standard multiple regression analysis as Tolerance, Variance inflation factor, normality, multicollinearity and cleanses from outliers. The positive R value, though small, informed the development of the multiple linear regression cost impact prediction equation in section 5.13.2.

Table 5.27: ANOVA of cost impact and influence of driving factors

Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
1	Regression	.990	9	.110	1.841	.065[a]
	Residual	9.443	158	.060		
	Total	10.434	167			

a. Predictors: (Constant), Contract information delay, Unstable foreign exchange, Cash flow problems, Variations to works, Fraud/corrupt practices, Inadequate prime cost and provisional sum, Contract manager's inexperience, Government's changes in policy and fiscal measures, Payment delays to the main contractor

b. Dependent Variable: Cost impact

Table 5.28: Model summary of the correlation between cost impact (cost overrun) and influence of driving factors

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.308[a]	.095	.043	.24448

a. Predictors: (Constant), Contract information delay (X_1), Unstable foreign exchange (X_2), Cash flow problems (X_3), Variations to works (X_4), Fraud/corrupt practices (X_5), Inadequate prime cost and provisional sum (X_6), Contract manager's inexperience (X_7), Government's changes in policy and fiscal measures (X_8), Payment delays to the main contractor (X_9).

b. Dependent Variable: Cost impact

5.13.1.2 Results of correlations test between time impact and influence of time drivers

In Table 5.29 the p-value 0.824 > 0.05, highly insignificant, indicating the rejection of the null hypothesis (H_0. The Correlation (R = 0.197) and R Square or coefficient of determination (0.039) which are positive (See Table 5.30) and the compliance of the survey data with technique of MLR general assumptions as Tolerance, Variance inflation factor, normality, multicollinearity and cleanses from outliers discussed in Chapter Four, Section 4.11.4.1 informed the research to progress to the development of multiple linear regression duration impact prediction equation in Section 5.13.2. However, the coefficient of determination = 0.039 implies that only 3.90% of time overrun is explained by influence of the driving factors.

Table 5.29: ANOVA of duration impact and influence of driving factors

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.684	10	.368	.586	.824[a]
	Residual	91.240	145	.629		
	Total	94.924	155			

a. Predictors: (Constant), Variation to works, Contractors' improper contract knowledge, Natural disaster such as flood, Cash flow problems, Non-performance of subcontractors, Delay in drawing preparations and approval, Design changes, Inadequate prime cost and provisional sum, Payment delays to the main contractor, Design errors

b. Dependent Variable: Duration impact

Table 5.30: Model summary of the correlation between time impact (time overrun) and influence of the driving factors

Model	R	R Square	Adjusted R Square	Std. error of the Estimate
1	.197[a]	.039	-.027	.79325

a. Predictors: (Constant), Variation to works, Contractors' improper contract knowledge, Natural disaster such as flood, Cash flow problems, Non-performance of subcontractors, Delay in drawing preparations and approval, Design changes, Inadequate prime cost and provisional sum, Payment delays to the main contractor, Design errors

b. Dependent Variable: Duration impact

5.13.2 The development of MLR cost prediction impact model

Using IBM SPSS Statistics version 21 standard multiple linear regressions on the 168 datasets (See Appendix XX) used in training the ANN cost impact model was used for computing the derivation of the cost impact linear equation. The MLR cost impact regression Equation 5.2 was obtained by substitution of the values of coefficients of each of the identified significant factors determined using the Pareto rule. When the constant value from the SPSS model coefficient Table 5.31 is substituted into the general regression expression Equation 5.1, the cost impact prediction model is thus:

Cost impact model (Y) = $\beta + X_1\alpha_1 + X_2\alpha_2 + X_3\alpha_3 + X_4\alpha_4 + X_5\alpha_5 + X_6\alpha_6 + X_7\alpha_7 + X_8\alpha_8 + X_9\alpha_9$.Equation 5.1

Cost impact model (Y) = $0.167 + 0.022X_1 – 0.002X_2 + 0.018X_3 + 0.002X_4 + 0.035X_5 + 0.003X_6 – 0.003X_7 – 0.019X_8 – 0.013X_9$. ……………………………………. Equation 5.2

Equation Y is the developed multiple linear regression (MLR) cost overrun or cost impact prediction equation. It shows that cost overrun has a positive relationship with contract information delay, cash flow problems, variation to works, fraud/corrupt practices and inadequate prime cost and provisional sum, while it has a negative relationship with unstable foreign exchange, government's change in policy and fiscal measures, payment delays to main contractor and contract manager's inexperience.

5.13.3 Contributions of individual independent variables (influence of factors) to the variances in the dependent variable (cost impact)

In Table 5.31, the contribution of each independent variable X_1 to X_9 can be fetched, the largest value is 0.035. It is fraud/corrupt practice which makes the strongest unique contribution to explaining the dependent variable – cost impact). X_5 (Fraud/corrupt practices)'s sig. value is $0.002 < 0.05$, it makes a statistically significant contribution to the prediction of cost overrun (Pallant, 2010). The part correlation coefficient 0.238, its square gives 0.054, indicating 5.4% of R square uniquely contributed by fraud and corrupt practices. The developed model explained 9.50 % (see Table 5.30) of the variance in cost overrun, where fraud or corrupt practices make the largest statistically significant contribution.

Table 5.31: Multiple linear regression cost impact model coefficients

		Unstandardized coefficients		Standardized coefficients	t	Sig.	95% confidence interval for B		Correlations			Collinearity statistics	
	Model	B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	.167	.069		2.398	.018	.029	.304					
	Contract manager's inexperience	.022	.013	.139	1.653	.100	-.004	.047	.141	.130	.125	.814	1.228
	Payment delays to main contractor	-.002	.013	-.011	-.132	.895	-.028	.025	.038	-.010	-.010	.799	1.252
	Unstable foreign exchange	.018	.014	.107	1.292	.198	-.010	.046	.138	.102	.098	.842	1.187
	Variations to works	.002	.014	.014	.174	.862	-.025	.030	.027	.014	.013	.881	1.135
	Fraud/corrupt practices	.035	.011	.254	3.076	.002	.012	.057	.231	.238	.233	.840	1.190
	Government's changes in policy and fiscal measures	.003	.015	.016	.190	.850	-.026	.032	.070	.015	.014	.822	1.216
	Inadequate prime cost and provisional sum	-.003	.015	-.015	-.175	.861	-.031	.026	.034	-.014	-.013	.821	1.218
	Cash flow problems	-.019	.014	-.117	-1.411	.160	-.046	.008	-.017	-.112	-.107	.829	1.206
	Contract information delay	-.013	.014	-.079	-.929	.354	-.041	.015	.006	-.074	-.070	.785	1.273

a. Dependent Variable: Cost impact

5.13.4 The development of the MLR time prediction impact model

Using IBM SPSS statistics version 21 standard multiple linear regression, the 159 datasets (See Appendix XXI) used in training the ANN construction time impact prediction model were used for the derivation of the MLR time impact prediction linear equation. The MLR time impact regression Equation 5.4 was obtained by substitution of the values of coefficients of each of the identified significant factors, which were determined using the Pareto rule and the constant from the SPSS model coefficient Table 5.32, substitutedinto the general regression expression Equation 5.3.

$Y = \gamma + X_1\delta_1 + X_2\delta_2 + X_3\delta_3 + X_4\delta_4 + X_5\delta_5 + X_6\delta_6 + X_{7\delta7} + X_8\delta_8 + X_9\delta_9 + X_{10}\delta_{10}$

$\therefore$ Duration impact (Y) = $\gamma + X_1\delta_1 + X_2\delta_2 + X_3\delta_3 + X_4\delta_4 + X_5\delta_5 + X_6\delta_6 + X_{7\delta7} + X_8\delta_8 + X_9\delta_9 +$ $X_{10}\delta_{10}$……………………………………………………………………………...Equation 5.3

$Y = 0.603 - 0.045X_1 + 0.066X_2 - 0.069X_3 - 0.013X_4 + 0.017X_5 - 0.003X_6 + 0.047X_7 + 0.004X_8 - 0.015X_9 - 0.011X_{10}$...Equation 5.4

Equation 5.4 (Y) is the developed multiple linear regression (MLR) or time overrun prediction equation. It shows that time overrun has a positive relationship with cash flow problems, delay in drawing preparations and approval, natural disaster such as flood, and non-performance of subcontractors, while it has a negative relationship with design errors, payment delays to the main contractor, inadequate prime cost and provisional sum, contractor's inadequate contract knowledge, design changes and variations to works.

5.13.5 Contributions of independent variables (Influence of factors) to the variances in the dependent variable (Time Impact)

Exploring the contribution of each independent variable X_1 to X_{10}, the largest value in Table 5.32 is 0.069, which records payment delays to the main contractor (makes the strongest unique contribution to explaining the dependent variable – cost overrun). X_3 (payment delays to the main contractor) which has the closet sig. value, is 0.172 > 0.05, a statistically nearer value to significance than the rest of the factors. The part correlation coefficient 0.112, its square gives 0.0125, indicating 1.25% of R square uniquely contributed by payment delays to the main contractor. The developed model explained 3.90 % (Table 5.30) of the variance in time overrun; payment delays to the main contractor make the largest statistically significant contribution.

Table 5.32: Multiple linear regression duration impact model coefficients

		Unstandardized Coefficients		Standardized Coefficients			95% Confidence Interval for B		Correlations			Collinearity Statistics	
	Model	B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	.603	.212		2.845	.005	.184	1.023					
	Design errors	-.045	.056	-.084	-.809	.420	-.155	.065	-.076	-.067	-.066	.610	1.640
	Cash flow problems	.066	.049	.122	1.340	.182	-.031	.162	.060	.111	.109	.799	1.251
	Payment delays to main contractor	-.069	.050	-.135	-1.371	.172	-.168	.030	-.104	-.113	-.112	.687	1.455
	Inadequate prime cost and provisional sum	-.013	.047	-.027	-.286	.775	-.107	.080	-.051	-.024	-.023	.732	1.366
	Delay in drawing preparations and approval	.017	.054	.030	.312	.756	-.089	.123	-.025	.026	.025	.722	1.384
	Contractors' improper contract knowledge	-.003	.046	-.005	-.055	.956	-.093	.088	-.010	-.005	-.005	.705	1.418
	Natural disaster such as flood	.047	.040	.104	1.168	.245	-.033	.127	.065	.097	.095	.831	1.203
	Non-performance of subcontractors	.004	.050	.008	.085	.932	-.094	.103	-.036	.007	.007	.756	1.323
	Design changes	-.015	.050	-.029	-.305	.761	-.114	.084	-.072	-.025	-.025	.750	1.334
	Variation to works	-.011	.055	-.020	-.202	.840	-.120	.098	-.090	-.017	-.016	.657	1.522

a. Dependent Variable: Duration impact

5.13.6 Development of artificial neural network impact prediction model

The correlations between the predictor (significant factors) and the dependent variables in MLR for both cost and time impact models are low, the factors could explain only less than 10% of the variance (impacts or overruns), and these suggest the inability of the technique to sufficiently pattern the relationship. This is unacceptable, it calls for the explorations of alternative modelling efforts, and Datt (2012) recommends an ANN approach. The modelling approach begins with (i) determination of network architecture (ii) learning process (iii) network training and testing. The modelling of the cost and duration impact assessment is conducted in the following subsections.

5.13.6.1 Artificial neural network model for construction cost impact prediction

The Pareto rule of 80/20 was used on the 43 cost influencing factors, and the top 20% yielded nine significant cost influencing factors (see Table 5.7) (Robert, 1987; Svenssson and Wood, 2006; Grosfeld-Nir et al., 2007). The factors (contract manager's inexperience, payment delay to main contractor, unstable foreign exchange, variations to works, fraud/corrupt practices, government's change in policy and fiscal measures, inadequate prime cost and provisional sum, cash flow problems and contract information delay) were taken forward as independent variables for modelling purposes. To determine the dependent variables for modelling purposes, the deviations between the contract sum and final account were computed from the collected secondary data. After removing the outliers, a total of 209 datasets was obtained, and these were used as dependent variables for modelling purposes.

ANN models are typically trained to learn the relationship pattern between project cost overrun and cost driving factors' influence. Initially, the 294 cases were trimmed from the incorrectly filled samples and later the removal of outliers. This resulted in 209 datasets used in the analysis. Out of these, 168 datasets (80%) (Odeyinka, 2003; Odeyinka et al., 2012; Odeyinka et al., 2013) were used for training the ANN model employed for predicting the impact of construction cost influencing factors on project cost performance. This was based on a 80:20 data partitioning ratio as used by Chakrabarti et al. (2009), Gunaydin and Dogan (2004) and Lee et al. (2018). The remaining 41 datasets were used for validating the model. The screen dump of the software cost impact prediction model is shown in Appendix XXIV. The Smart Lab ANN software was used in training the pair of independent and dependent variables. An Artificial Neural Network (ANN) cost overrun prediction model shown in Figure 5.3 was developed for predicting the levels of project cost performance, using construction cost influencing factors and the ratios of cost deviations.

The model training commenced with a 70% / 30% data partition, and new datasets were added to adjust the samples to 80% / 20% (Kulkarni et al., 2017) as the performance of the model was not meeting expectations (Zhang and Fuh, 1998). In similar trials by Gunaydin and Dogan (2004), Odeyinka (2003), Odeyinka et al. (2012) and Odeyinka et al. (2013) the network was found to stabilize at the 80:20 data partition with two hidden layers of 18 hidden nodes.

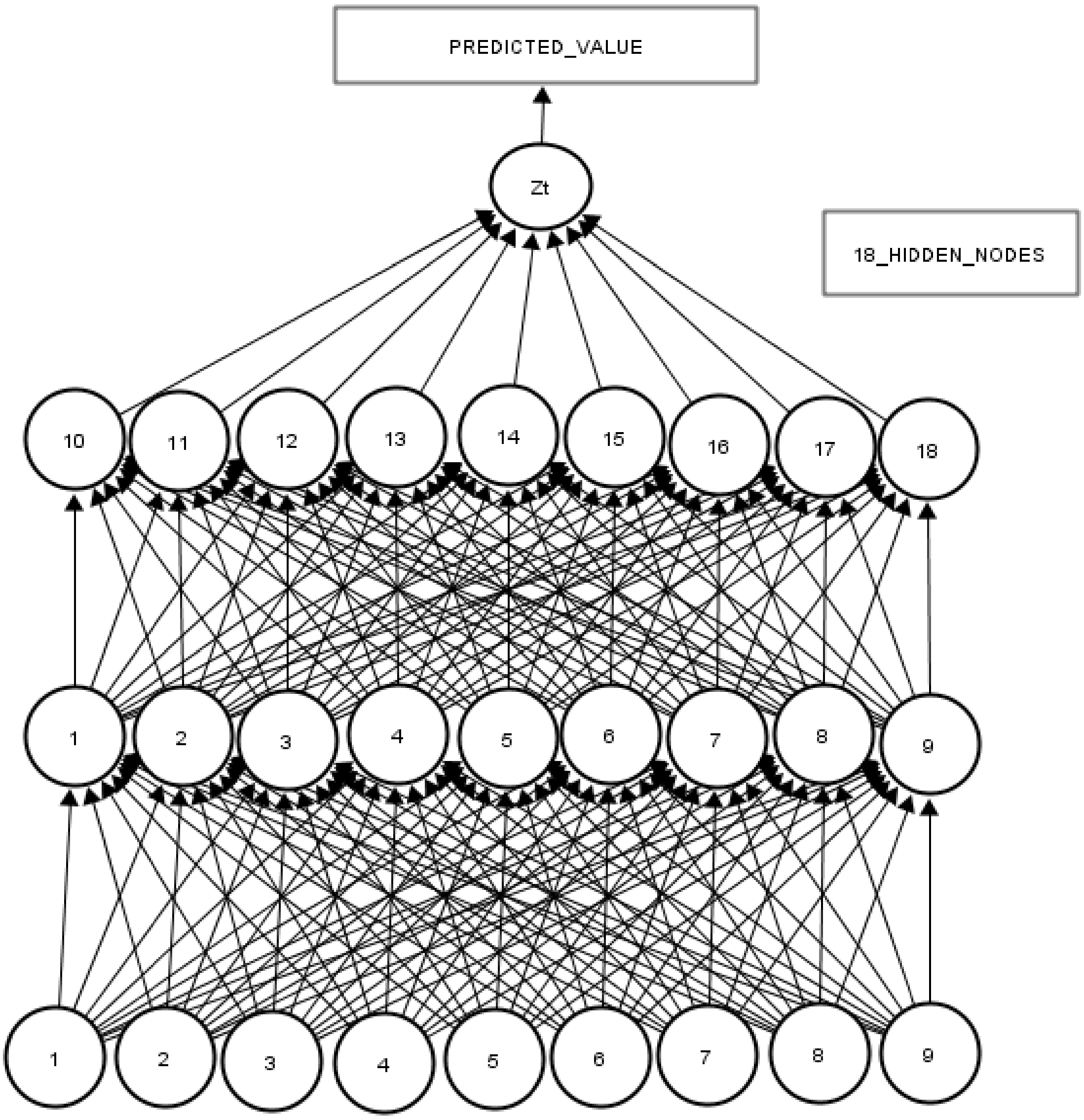


Figure 5.3: Artificial neural network architecture employed for assessing cost impacts on the initial contract sum

An effective number of processing elements is usually determined by trials for the hidden layers, since there is no rule to determine it (Albino and Garavelli, 1998; Rafiq et al., 2001; Setyawati et al., 2002; Shtub and Versano, 1999). Finally, the model morphed into a 9-9-9-1 back propagation architecture as shown in the screen dump of the software in Figure 5.5. The rate for the best network of all the trials for this segment of the research is 0.75, with 5 288 training cycles. Training error was set to be reduced to 0.001. After 5 288 training cycles (epochs) (Kalogirou, 2001; Petruseva et al., 2013), the root mean square (RMS) for the training samples was found to be 0.076. This suggests that the system had learned the relationships between the inputs and outputs and could also generalize from data. The network architecture together with the associated weight matrixes shown in Fig 5.4 then became a model for assessing the impact of construction costs on the construction project initial contract sum.

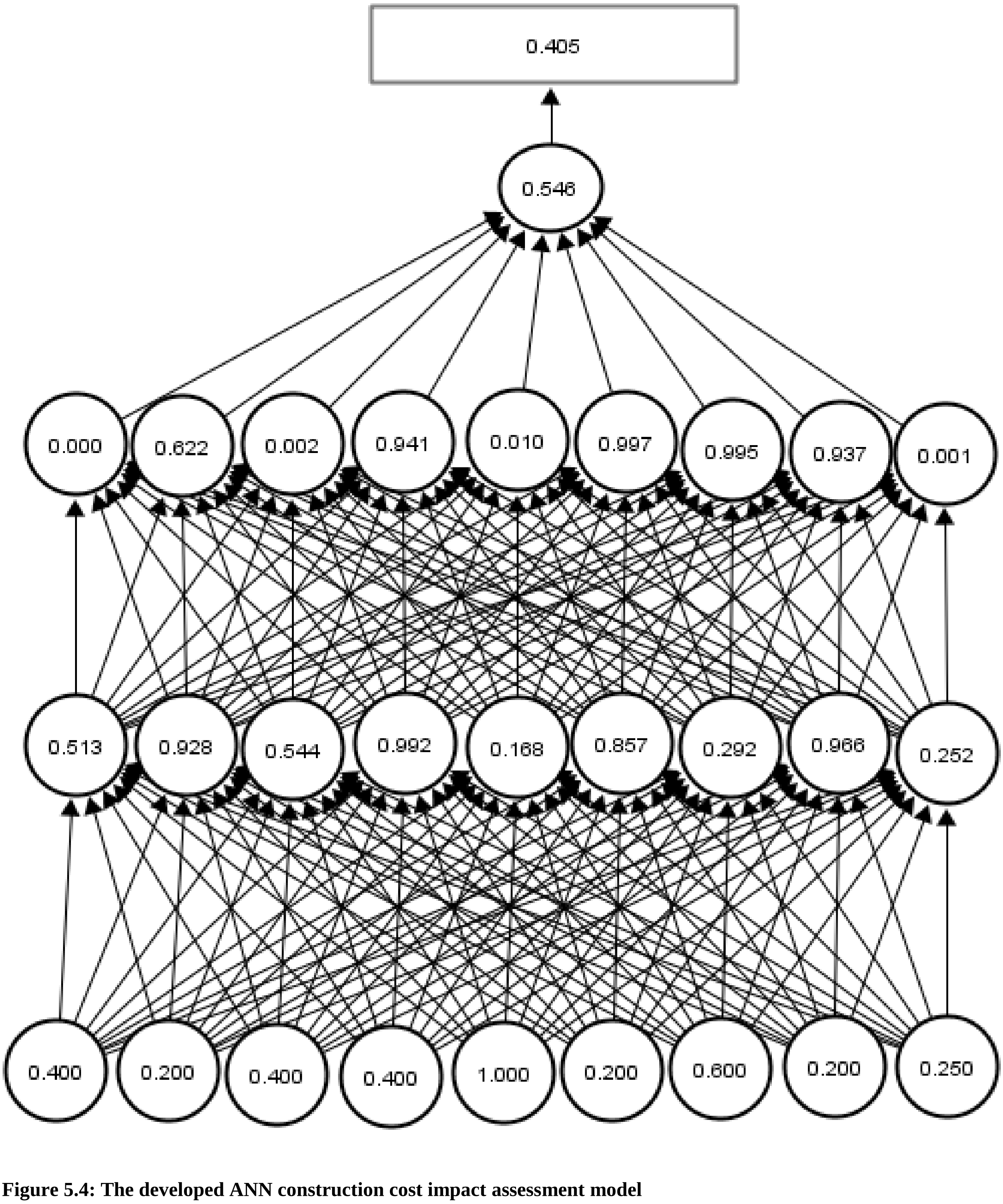


Figure 5.4: The developed ANN construction cost impact assessment model

5.13.6.2 Artificial neural network model for construction time impact prediction

Using the Pareto rule of 80/20, the top 20% of the 49 cost influencing factors yielded ten significant time influencing factors (see Table 5.10) (Grosfeld-Nir et al., 2007; Robert, 1987;

Svenssson and Wood, 2006). The factors are: design errors, cash flow problems, payment delay to main contractor, contractor's inadequate contract knowledge, delay in drawing preparation and approval, inadequate prime cost and provisional sum, design changes, natural disaster such as flood, variations to works, and non-performance of subcontractors, and they were taken forward as independent variables for modelling purposes. To determine the dependent variables for modelling purposes, the deviations between the estimated construction durations and actual construction durations were computed from the collected secondary data. After removing the outliers, a total of 199 datasets were obtained from completed construction projects, and these were used as dependent variables for modelling purposes.

The Smart Lab ANN software was used in training the pair of independent and dependent variables. A total of 159 datasets representing 80% of the survey data (See Appendix XXI) were used for the ANN duration impact model training, 39 datasets were reserved for use in validating the trained model. Like Section 5.13.6.1 Artificial neural network model for construction cost impact prediction; The model training data started with a 70%/30% partition, but after several trials (Bhokha and Ogunlana, 1999), more data was added to stabilize the network at 80%/20% (Kulkarni et al., 2017) partition which resulted to 10-6-6-1 network configuration. The impact model training cycles (epochs) (Kalogirou, 2001) were 1 534 and 0.80 learning error. Training error was set to be reduced to 0.001, while the RMS from the screen was 0.024. The screen dump of the trained and stabilized ANN duration impact assessment network model is shown in Appendix XXV. As shown in Figures 5.5 and 5.6, the model architecture consists of ten input nodes (independent variables), two hidden layers of six nodes each and one output node (dependent variable).

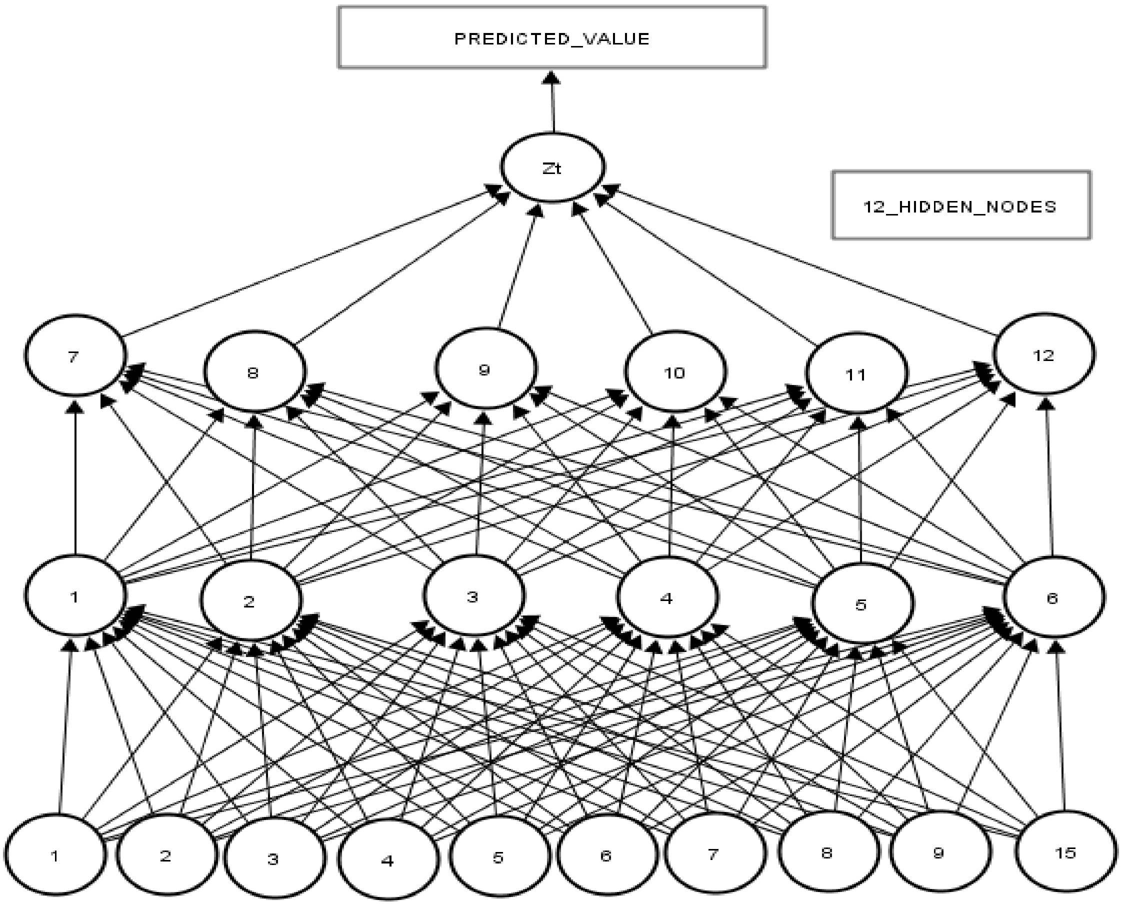


Figure 5.5: ANN duration impact prediction model architecture

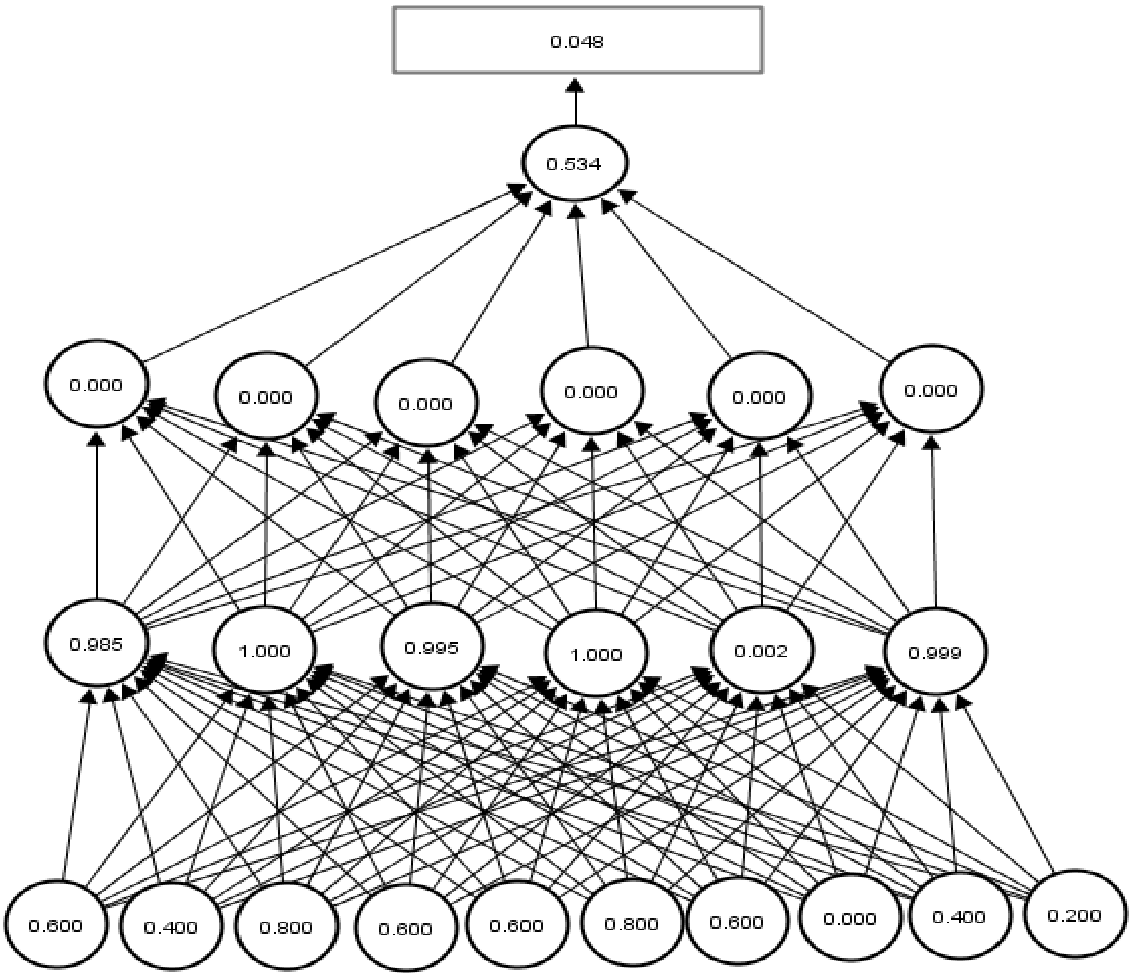


Figure 5.6: The developed ANN construction duration impact assessment model

5.13.6.3 Comparison of the study's MLR and ANN cost and duration models' predictive powers

Studies on the application of ANN techniques to predict construction cost and time performance often compare the accuracy of ANN with multiple linear regression MLR (Aibinu et al., 2015; Bode, 1998; Bode, 2000; Chen & Hartman, 2000; Chen et al., 2013; Creese and Li, 1995; Garza and Rouhana, 1995; Gunaydin and Dogan; 2004; Kim et al., 2004; Odeyinka, 2003; Smith and Mason, 1997; Shtub and Versano, 1999; Sonmez, 2004; Squeira, 1999; and Yeh, 1998a).

This study conceptualized in Chapter 3 that ANN models are more viable alternatives to MLR when modelling the cost and time overruns of building projects, because the relationship between the cost and time influencing variables are subtle, non-linear and may be unknown. In developing MLR models for predicting the impact of construction cost and time driving factors, the coefficient of determination, R^2, the indicator of the percentage of the impacts explained by predictors, was found to be very low and unacceptable (see Table 5.34). The R-squared are below 10% in each case, and the probability values (Sig. > 0.05) indicated acceptance of the null hypotheses. The conceptualized alternatives, namely the ANN models, were developed, tested and validated. The performance of the MLR regression and ANN models was then compared in Tables 5.33 and 5.34. The MLR models, though they were poor at mapping the relationships between the factors' influences and impacts, were still found to have relative absolute deviations (Rel.MAD) of 0.70 and 1.37, for cost and time impact models respectively. The ANN models were found with 1.46 and 0.85 relative absolute deviations for cost and time impact respectively. Also, the MLR mean absolute percentage errors (MAPE) are 4.3% and 5.6% for the cost and duration impact models respectively and the ANNs' are 6.5% and 7.1% for cost and time impact models. Except for the ANN duration prediction model which has Rel.MAD of 0.85, the MLR model seems to have better predictive powers.

However, because of the MLR's poor mapping of the relationship between the dependent and independent variables depicted in Table 5.35, the study upholds the view that artificial neural networks (ANN) are a better alternative to multiple linear regression MLR analytical techniques in the assessment of construction project cost and duration performance. This finding supports the results of previous studies such as those by Aibinu et al. (2015), Kim et al. (2004) and Yeh (1998b). That most systems in real life are not linear and ordered but, non-linear, complex and dynamic, is becoming more and more recognized (Bertelson, 2014).

Table 5.33: Comparison of MLR and ANN cost impact assessment models

S/No	Actual Cost Impact	MLRM Cost Impact Prediction	Absolute Deviation	Square Error	ANNM Impact Prediction	Absolute Deviation	Square Error
1	0.05	0.370	-5.98	0.10	0.49	-8.19	0.19
2	0.17	0.150	0.10	0.00	0.64	-2.83	0.22
3	0.11	0.260	-1.30	0.02	0.90	-6.98	0.62
4	0.20	0.210	-0.07	0.00	0.15	0.23	0.00
5	0.22	0.280	-0.28	0.00	0.79	-2.64	0.33
6	0.53	0.240	0.54	0.08	0.21	0.60	0.10
7	0.92	0.260	0.72	0.43	-0.08	1.08	0.98
8	0.80	0.430	0.46	0.13	0.19	0.77	0.37
9	0.58	0.360	0.38	0.05	0.25	0.57	0.11
10	0.08	0.210	-1.73	0.02	0.15	-0.95	0.01
11	0.58	0.280	0.52	0.09	0.16	0.72	0.18
12	-0.02	0.390	22.67	0.17	0.08	5.17	0.01
13	0.39	0.280	0.29	0.01	-0.17	1.42	0.31
14	0.32	0.190	0.40	0.02	0.45	-0.41	0.02
15	0.15	0.340	-1.22	0.03	0.56	-2.63	0.16
16	0.09	0.170	-0.85	0.01	0.53	-4.73	0.19
17	0.75	0.380	0.49	0.14	0.32	0.57	0.18
18	0.13	0.160	-0.26	0.00	0.50	-2.95	0.14

S/No	Actual Cost Impact	MLRM Cost Impact Prediction	Absolute Deviation	Square Error	ANNM Impact Prediction	Absolute Deviation	Square Error
19	0.47	0.220	0.53	0.06	0.51	-0.09	0.00
20	0.33	0.370	-0.11	0.00	0.08	0.77	0.07
21	0.56	0.240	0.57	0.10	0.72	-0.28	0.03
22	0.96	0.270	0.72	0.47	-0.03	1.03	0.96
23	0.24	0.330	-0.35	0.01	0.71	-1.92	0.22
24	0.19	0.370	-0.95	0.03	0.55	-1.92	0.13
25	0.32	0.120	0.63	0.04	0.90	-1.77	0.33
26	0.10	0.280	-1.83	0.03	-0.11	2.07	0.04
27	0.58	0.360	0.38	0.05	0.00	0.99	0.34
28	0.61	0.260	0.58	0.13	0.68	-0.11	0.00
29	0.14	0.400	-1.90	0.07	0.30	-1.17	0.03
30	0.06	0.380	-5.91	0.11	0.42	-6.56	0.13
31	0.17	0.280	-0.68	0.01	0.33	-0.97	0.03
32	0.11	0.350	-2.13	0.06	0.49	-3.35	0.14
33	0.56	0.270	0.51	0.08	0.73	-0.31	0.03
34	0.12	0.280	-1.35	0.03	0.13	-0.11	0.00
35	0.04	0.250	-4.68	0.04	0.43	-8.82	0.15
36	0.05	0.430	-7.11	0.14	0.41	-6.81	0.13
37	0.04	0.390	-9.26	0.12	0.36	-8.37	0.10
38	0.04	0.370	-7.41	0.11	0.03	0.41	0.00
39	0.13	0.310	-1.37	0.03	0.10	0.26	0.00
40	0.22	0.350	-0.60	0.02	0.34	-0.56	0.02
41	0.12	0.370	-1.98	0.06	0.26	-1.11	0.02
			-28.81	3.11		-59.88	7.02
	Rel.MAD/MSE		0.70	0.043		1.46	0.065

Table 5.34: Comparison of MLR and ANN duration impact assessment models

S/No	Actual Impact	MLRM Duration Impact Prediction	Absolute Deviation	Square Error	ANNM Duration Impact Prediction	Absolute Deviation	Square Error
1	0.17	0.63	-2.71	0.21	0.61	-2.56	0.19
2	0.10	0.35	-2.50	0.06	-0.27	3.67	0.13
3	0.25	0.51	-1.04	0.07	-0.25	2.01	0.25
4	0.43	0.59	-0.37	0.03	0.08	0.80	0.12
5	0.20	0.63	-2.15	0.18	0.11	0.44	0.01
6	0.71	0.33	0.54	0.14	-0.31	1.44	1.04
7	0.19	0.43	-1.26	0.06	0.04	0.81	0.02
8	0.10	0.52	-4.20	0.18	-0.61	7.13	0.51

S/No	Actual Impact	MLRM Duration Impact Prediction	Absolute Deviation	Square Error	ANNM Duration Impact Prediction	Absolute Deviation	Square Error
9	0.64	0.52	0.19	0.01	0.49	0.24	0.02
10	0.47	0.67	-0.43	0.04	-0.01	1.03	0.23
11	0.36	0.37	-0.03	0.00	0.17	0.53	0.04
12	0.20	0.50	-1.50	0.09	-0.46	3.29	0.43
13	0.50	0.50	0.00	0.00	0.30	0.40	0.04
14	0.33	0.50	-0.52	0.03	-0.64	2.93	0.94
15	0.33	0.71	-1.15	0.14	0.02	0.95	0.10
16	-0.50	0.68	2.36	1.39	0.00	1.01	0.25
17	0.39	0.38	0.03	0.00	0.61	-0.55	0.05
18	0.46	0.43	0.07	0.00	-0.30	1.66	0.58
19	0.12	0.32	-1.67	0.04	0.05	0.59	0.01
20	0.06	0.42	-6.00	0.13	0.06	0.07	0.00
21	0.29	0.57	-0.97	0.08	0.47	-0.62	0.03
22	0.38	0.70	-0.84	0.10	0.54	-0.42	0.02
23	0.31	0.60	-0.94	0.08	-0.01	1.05	0.10
24	0.43	0.31	0.28	0.01	0.53	-0.24	0.01
25	0.08	0.39	-3.88	0.10	0.15	-0.81	0.00
26	0.38	0.13	0.66	0.06	-0.41	2.09	0.63
27	0.10	0.42	-3.20	0.10	0.06	0.44	0.00
28	0.12	0.43	-2.58	0.10	0.07	0.44	0.00
29	0.25	0.58	-1.32	0.11	0.07	0.73	0.03
30	0.25	0.55	-1.20	0.09	0.07	0.74	0.03
31	0.20	0.48	-1.40	0.08	0.07	0.67	0.02
32	0.26	0.90	-2.46	0.41	0.29	-0.11	0.00
33	0.24	0.36	-0.50	0.01	0.56	-1.33	0.10
34	0.29	0.43	-0.48	0.02	-0.66	3.26	0.89
35	0.08	0.28	-2.50	0.04	0.13	-0.60	0.00
36	0.10	0.67	-5.70	0.32	0.06	0.42	0.00
37	0.13	0.57	-3.38	0.19	0.54	-3.18	0.17
38	0.47	0.62	-0.32	0.02	-0.01	1.03	0.23
39	0.15	0.23	-0.53	0.01	-0.42	3.78	0.32
			-53.61	4.76		33.21	7.59
		Rel.MAD/MSE	1.37	0.056		0.851538	0.071

Table 5.35: Multiple linear regression correlation statistics of impact and influence of the cost and time driving factors

S/No	Cost model	Duration model
1.	R = 0.308	R = 0.197
2.	R^2 = 0.095 (9.50%)	R^2 = 0.039 (3.9%)
3.	Sig. = 0.065 > 0.05	Sig = 0.824 > 0.05

5.14 Validating the developed cost and time performance impact assessment models of public buildings in the study area

The sixth objective of the research is to validate the developed cost and time performance impact assessment models of public buildings in the study area. Validations of the prediction efficacies of the developed impact models are presented in a separate chapter (Chapter 6) of this report.

5.15 Summary of data presentation, analysis and discussions

Background details of the research respondents were presented in the chapter. Construction cost and time factors were assessed and discussed in the light of past studies. The cost and time drivers were respectively reduced to five, and seven factor-components. This was done by means of factor analysis, using the principal component approach. The Pareto rule of 80% / 20% was used on the 43 and 49 cost and time drivers to determine the significant factors. The mean cost and time performances of constructions in small or uncomplicated, medium or moderately complex and large or complex projects were investigated. Also investigated were the impact of project complexities on the construction cost and time. The results showed that the construction cost performance between small or uncomplicated and medium or moderately complex projects is not significant, while it was significant between small or uncomplicated and large or complex projects. Between medium or moderately complex and large or complex projects, the construction cost performance was also significant. Construction time performances between small or uncomplicated and medium or moderately complex as well as large or complex projects were found significant. The time performance between medium or moderately complex and large or complex project was however, not significant. It was found in the study that there is a statistically significant difference in the project complexity cost impact performance, between small or uncomplicated, and large or complex construction projects. The same was also found of the complexity impacts on cost performace of the medium or moderately complex and large or complex projects. The mean cost performance impact differentials between small or uncomplicated and medium or moderately complex construction projects was found not significant. Project complexity impact differentials across the three classes of construction projects on time performance were found not significant. The implications of the results were discussed in the sections. The design of cost and duration MLR impact prediction equations were based on the R-squared and Sig values of the multilinear correlations between the factors' influences and the impacts. ANN impact models were developed as alternatives to MLR construction impact assessment models, because of the weakness of MLR models to pattern the non-linear relationships among the multiple cost and time influence factors. The research objectives 1, 2, 3, 4 and 5 were thus achieved in the chapter.

CHAPTER SIX: VALIDATION OF THE DEVELOPED MODELS

6.1 Introduction

In the last chapter, attempts were made to test the levels of correlation between the influence of costs and time factors with their corresponding impacts (overruns). The positive correlations (R) found, and explanations of variance in the dependent variables by the independent variables, indicated by the coefficient of determination (R-square) informed the design of MLR equations predicting cost and time impact. Artificial neural network (ANN) analysis technique was explored as an alternative prediction technique as the values of R-squared obtained were low. This indicated the inability of MLR to sufficiently map the relationship between the independent input variables with the dependent or output variables (cost and time impacts). The prediction efficacies of the impact prediction models obtained from both techniques are validated in this chapter.

6.2 Validations of MLR and ANN impact assessment models

Developed models in research are normally validated to test against established performance criteria, and the test performance recorded. The information could be used in remoulding, restructuring and demodulation (Amusan, 2011). Once the stability of the generated output had been confirmed, the forecast result is treated as a model that could later be developed and abstracted for further use. The MLR duration impact equations and the conceptualized ANN construction cost and duration impact assessment models are validated in the following sections, with new datasets.

6.2.1 MLR impact assessment models

Multiple linear regression impact prediction equations were derived with same 168 datasets used in training the ANN cost and time impact models. The developed mathematical equations were used in predicting cost and time impacts also with the same new dataset as ANN models. First is the MLR cost impact prediction equation.

6.2.1.1 Validation of MLR cost impact equation

The developed MLR mathematical model Equation 5.2 was fed the 41 new datasets reserved for validations (See Appendix XXII) as the ANN cost impact model. The survey data were substituted into the linear Equation 5.2. The computed relative mean absolute deviation 0.70 and the mean absolute percentage error 4.30% are presented in the model validation Table 6.1. It can be inferred from the table that using the developed MLR equation for cost overrun predictions, the predicted values are not likely to deviate from the expected percentage by more than a plus or minus 0.70; in that case, the percentage efficiency of the predicted values will be 95.70% that is (100.00 – 4.30).

However, the adjusted R-squared 0.043 in Table 5.22 implies that the 4.30 per cent explanation of the cost impact or cost overrun by the significant factors is small and therefore unacceptable. The small value of the adjusted R square is evidence of the multiple linear impact prediction to model adequately the pattern in the relationship between the dependent (output) and independent (input) variables. The inadequate relationship mapping suggests the existence of a non-linear or unknown relationship between the input (independent) and output (dependent) variables.

Table 6.1: Multiple linear regression cost impact model validation

S/No	Actual Cost Impact	MLRM Predicted Cost Impact	Absolute Deviation	Square Error
1	0.05	0.370	-5.98	0.10
2	0.17	0.150	0.10	0.00
3	0.11	0.260	-1.30	0.02
4	0.20	0.210	-0.07	0.00
5	0.22	0.280	-0.28	0.00
6	0.53	0.240	0.54	0.08
7	0.92	0.260	0.72	0.43
8	0.80	0.430	0.46	0.13
9	0.58	0.360	0.38	0.05
10	0.08	0.210	-1.73	0.02
11	0.58	0.280	0.52	0.09
12	-0.02	0.390	22.67	0.17
13	0.39	0.280	0.29	0.01
14	0.32	0.190	0.40	0.02
15	0.15	0.340	-1.22	0.03
16	0.09	0.170	-0.85	0.01
17	0.75	0.380	0.49	0.14
18	0.13	0.160	-0.26	0.00
19	0.47	0.220	0.53	0.06
20	0.33	0.370	-0.11	0.00
21	0.56	0.240	0.57	0.10
22	0.96	0.270	0.72	0.47
23	0.24	0.330	-0.35	0.01
24	0.19	0.370	-0.95	0.03
25	0.32	0.120	0.63	0.04
26	0.10	0.280	-1.83	0.03
27	0.58	0.360	0.38	0.05
28	0.61	0.260	0.58	0.13
29	0.14	0.400	-1.90	0.07
30	0.06	0.380	-5.91	0.11
31	0.17	0.280	-0.68	0.01
32	0.11	0.350	-2.13	0.06
33	0.56	0.270	0.51	0.08
34	0.12	0.280	-1.35	0.03
35	0.04	0.250	-4.68	0.04
36	0.05	0.430	-7.11	0.14
37	0.04	0.390	-9.26	0.12
38	0.04	0.370	-7.41	0.11
39	0.13	0.310	-1.37	0.03

S/No	Actual Cost Impact	MLRM Predicted Cost Impact	Absolute Deviation	Square Error
40	0.22	0.350	-0.60	0.02
41	0.12	0.370	-1.98	0.06
			-28.81	3.11
	Rel.MAD/MSE		0.70	0.0430

6.2.1.2 Validation of MLR duration impact equation

The developed MLR mathematical model Equation 5.4 was used to predict the time impact of the same 39 new datasets (See Appendix XXIII) also used for the ANN time impact model. The multiple linear regression time impact model validation is presented on substitutions of the survey input values into the linear Equation 5.4. The computed relative mean absolute deviation 1.37 and the mean absolute percentage error 5.56% are presented in the model validation Table 6.2. It can be inferred from the table that using the developed MLR equation for cost overrun predictions, the predicted values are not likely to deviate from the expected by a plus or minus 1.37, or the percentage efficiency of the predicted values is 94.41%.

Table 6.2: Multiple linear regression duration impact model validation

S/No	Actual Duration Impact	MLR Duration Impact	Absolute deviation	Square Error
1	0.17	0.63	-2.71	0.21
2	0.10	0.35	-2.50	0.06
3	0.25	0.51	-1.04	0.07
4	0.43	0.59	-0.37	0.03
5	0.20	0.63	-2.15	0.18
6	0.71	0.33	0.54	0.14
7	0.19	0.43	-1.26	0.06
8	0.10	0.52	-4.20	0.18
9	0.64	0.52	0.19	0.01
10	0.47	0.67	-0.43	0.04
11	0.36	0.37	-0.03	0.00
12	0.20	0.50	-1.50	0.09
13	0.50	0.50	0.00	0.00
14	0.33	0.50	-0.52	0.03
15	0.33	0.71	-1.15	0.14
16	-0.50	0.68	2.36	1.39
17	0.39	0.38	0.03	0.00
18	0.46	0.43	0.07	0.00
19	0.12	0.32	-1.67	0.04
20	0.06	0.42	-6.00	0.13
21	0.29	0.57	-0.97	0.08
22	0.38	0.70	-0.84	0.10
23	0.31	0.60	-0.94	0.08
24	0.43	0.31	0.28	0.01
25	0.08	0.39	-3.88	0.10

S/No	Actual Duration Impact	MLR Duration Impact	Absolute deviation	Square Error
26	0.38	0.13	0.66	0.06
27	0.10	0.42	-3.20	0.10
28	0.12	0.43	-2.58	0.10
29	0.25	0.58	-1.32	0.11
30	0.25	0.55	-1.20	0.09
31	0.20	0.48	-1.40	0.08
32	0.26	0.90	-2.46	0.41
33	0.24	0.36	-0.50	0.01
34	0.29	0.43	-0.48	0.02
35	0.08	0.28	-2.50	0.04
36	0.10	0.67	-5.70	0.32
37	0.13	0.57	-3.38	0.19
38	0.47	0.62	-0.32	0.02
39	0.15	0.23	-0.53	0.01
			-53.61	4.76
	ReL.MAD/MSE		1.37	0.0559

However, the adjusted R-squared -0;027 in Table 5.24 implies that the -2.70% per cent explanation of the time impact or time overrun by the significant factors is small and therefore unacceptable. The small value of the adjusted R square is evidence of the multiple linear impact prediction to model adequately pattern the relationship between the dependent (output) and independent (input) variables. The inadequate relationship patterning suggests the existence of a non-linear or unknown relationship between the input (independent) and output (dependent) variables.

6.2.2 Validations of the developed artificial neural network impact assessment models

The trained and stabilized models are validated with new datasets for global acceptance in the following sections using relative mean absolute deviation and mean square error, or root mean square (RMS) statistics.

6.2.2.1 Artificial neural network cost impact assessment model

The trained and stabilized ANN cost model was validated with 41 new datasets (see Appendix XXII, representing 20% of the survey data) for global acceptance, to derive the relative mean absolute deviation (Rel. MAD) and mean square error (MSE), root mean square (RMS) statistics or mean absolute error (MAPE). These were chosen because deviations are measured in absolute terms while MAPE allows for comparisons with similar studies. The formulae for the measures are as given earlier in Equations 3.4 and 3.5 in Chapter 3 section 3.7. Input data (influence of driving factors) and output data (cost impacts or cost overruns) were entered in the software, and the network requested to forecast the cost impacts which are ratios of the differentials between initial and final costs on the initial costs. The outputs are shown on the screen dump shown in Appendix XXIV. For instance, from the screen dump, the output value for the first input data is displayed as 0.405. The validation tests performed on the networks were a comparison between the predicted and the actual impacts obtained from the test data.

The study determined that the Mean Square Error (MSE) and the Relative Mean Absolute Deviation (Rel. MAD) measures are 6.46% and 1.46 respectively, while deviation ranged between -8.37 and 5.17 isshown in Table 6.3. It can be deduced from these findings that the trained and stabilized ANN cost model is valid. Therefore, the driving factors used — contract information delay, unstable foreign exchange, cash flow problems, variations to works, fraud/corrupt practices, inadequate prime cost and provisional sum, inexperience of the contract manager, government's policy and fiscal measures and payment delays to main contractors — are predictors of cost overruns. The prediction efficiency of the developed cost impact prediction model is 93.54% (100 – 6.46) in predicting cost overruns on future projects. Moreover, the deviation between the predicted and actual cost overrun figures on the average is plus or minus 1.46.

Table 6.3: Artificial neural network cost impact model validation

S/No	Act. Imp	Pre. Imp	(Act. - Pre.)/Act	Square Error
1	0.05	0.49	-8.19	0.19
2	0.17	0.64	-2.83	0.22
3	0.11	0.90	-6.98	0.62
4	0.20	0.15	0.23	0.00
5	0.22	0.79	-2.64	0.33
6	0.53	0.21	0.60	0.10
7	0.92	-0.08	1.08	0.98
8	0.80	0.19	0.77	0.37
9	0.58	0.25	0.57	0.11
10	0.08	0.15	-0.95	0.01
11	0.58	0.16	0.72	0.18
12	-0.02	0.08	5.17	0.01
13	0.39	-0.17	1.42	0.31
14	0.32	0.45	-0.41	0.02
15	0.15	0.56	-2.63	0.16
16	0.09	0.53	-4.73	0.19
17	0.75	0.32	0.57	0.18
18	0.13	0.50	-2.95	0.14
19	0.47	0.51	-0.09	0.00
20	0.33	0.08	0.77	0.07
21	0.56	0.72	-0.28	0.03
22	0.96	-0.03	1.03	0.96
23	0.24	0.71	-1.92	0.22
24	0.19	0.55	-1.92	0.13
25	0.32	0.90	-1.77	0.33
26	0.10	-0.11	2.07	0.04
27	0.58	0.00	0.99	0.34

S/No	Act. Imp	Pre. Imp	(Act. - Pre.)/Act	Square Error
28	0.61	0.68	-0.11	0.00
29	0.14	0.30	-1.17	0.03
30	0.06	0.42	-6.56	0.13
31	0.17	0.33	-0.97	0.03
32	0.11	0.49	-3.35	0.14
33	0.56	0.73	-0.31	0.03
34	0.12	0.13	-0.11	0.00
35	0.04	0.43	-8.82	0.15
36	0.05	0.41	-6.81	0.13
37	0.04	0.36	-8.37	0.10
38	0.04	0.03	0.41	0.00
39	0.13	0.10	0.26	0.00
40	0.22	0.34	-0.56	0.02
41	0.12	0.26	-1.11	0.02
			59.88	7.02
		Rel.MAD	1.46	
		Maximum	5.17	
		Minimum	-8.37	
			MSE	0.0646

6.2.2.2 Artificial neural network duration impact model

In a similar process to 6.2.2.1, the remaining 39 datasets (See Appendix XXIII) representing 20% of the survey data were used to test the forecasting accuracy of the duration impact model. Input data or influence of the driving factors, and output data (duration impacts or time overruns) were entered, and the network requested to forecast the cost impact which are; ratios of the difference between initial and final costs on the initial costs. The outputs are shown on the screen dump in Appendix XXV. The validation tests performed on the networks were a comparison between the predicted and the actual impacts obtained from the test data. The statistical verification methods employed are the mean absolute percentage error (MAPE) or root mean square (RMS), as shown by Equation 3.13, and relative mean absolute deviation (Rel. MAD) shown by Equation 3.14. These were chosen because Rel. MAD are measured in absolute terms, while the MAPE allows for comparisons with similar past studies. The Rel. MAD measures for each of the 39 datasets used in testing the model are shown in Table 6.4. The MAPE and Rel. MAD of the developed duration impact model statistics are 7.06% and 0.85 respectively, while deviation ranges between -3.18 and 7.13. Therefore, the driving factors used (design errors, cash flow problems, payment delay to main contractor, contractor's inadequate contract knowledge, delay in drawing preparations and approval, inadequate prime cost and provisional sum, design changes, natural disaster such as flood, variations to works and non-performance of subcontractors) are predictors of time overruns.

Table 6.4: Artificial neural network duration impact model validation

S/No	Actual Impact	Prediction Impact	(Actual-Prediction)/Actual	Square Error
1	0.17	0.61	-2.56	0.19
2	0.10	-0.27	3.67	0.13
3	0.25	-0.25	2.01	0.25
4	0.43	0.08	0.80	0.12
5	0.20	0.11	0.44	0.01
6	0.71	-0.31	1.44	1.04
7	0.19	0.04	0.81	0.02
8	0.10	-0.61	7.13	0.51
9	0.64	0.49	0.24	0.02
10	0.47	-0.01	1.03	0.23
11	0.36	0.17	0.53	0.04
12	0.20	-0.46	3.29	0.43
13	0.50	0.30	0.40	0.04
14	0.33	-0.64	2.93	0.94
15	0.33	0.02	0.95	0.10
16	-0.50	0.00	1.01	0.25
17	0.39	0.61	-0.55	0.05
18	0.46	-0.30	1.66	0.58
19	0.12	0.05	0.59	0.01
20	0.06	0.06	0.07	0.00
21	0.29	0.47	-0.62	0.03
22	0.38	0.54	-0.42	0.02
23	0.31	-0.01	1.05	0.10
24	0.43	0.53	-0.24	0.01
25	0.08	0.15	-0.81	0.00
26	0.38	-0.41	2.09	0.63
27	0.10	0.06	0.44	0.00
28	0.12	0.07	0.44	0.00
29	0.25	0.07	0.73	0.03
30	0.25	0.07	0.74	0.03
31	0.20	0.07	0.67	0.02
32	0.26	0.29	-0.11	0.00
33	0.24	0.56	-1.33	0.10
34	0.29	-0.66	3.26	0.89
35	0.08	0.13	-0.60	0.00
36	0.10	0.06	0.42	0.00
37	0.13	0.54	-3.18	0.17
38	0.47	-0.01	1.03	0.23
39	0.15	-0.42	3.78	0.32
			33.21	7.59
		Rel.MAD	0.85	
		Maximum	7.13	
		Minimum	-3.18	
			MSE	0.0706

6.3 A comparison of the developed ANN impact models with previous researches

The ANN mean absolute percentage error (MAPE) obtained in this research (6.5%) compares favourably with values obtained from previous studies. It can be seen in Table 6.5 that the

MAPE of this research is 6.5%. Excepting Pewdum et al. (2009) which MAPE is 6.40%, this study has a higher precision than Aibinu et al. (2015), Al-Tabtabai et al. (1999), Emsley et al. (2002) and Siqueira (1999) which values are 8.10%, 8.51%, 11% and 16.6% respectively. However, some more precise models by Amusan (2011), Kim et al. (2004), Kim et al. (2013) and Petruseva et al. (2013) are available. The MAPEs are 5.27%, 2.97%, 2.50% and 1.14%, though the models are for total building cost and construction duration estimation.

Also, in Table 6.5, this research's ANN cost impact model Rel.MAD (1.46) value compares favourably with that of Kaur (2016) whose values ranged between 1.70 and 2.60. Gunaydin and Dogan's (2004) early cost estimation of structural systems of buildings produced an ANN network model of very high precision which Rel.MAD was 0.12.

Table 6.5: Performance measurements of MLR and ANN models related to past studies

S/No	Author and study	Mean absolute percentage error (MAPE)	
		MLR	**ANN**
	This study		
1.	Cost	4.3%	6.5%
	Time	5.6%	7.1%
	Previous studies		
2.	Squeira (1999) Cost estimating of structural steel framing	15%	11%
		21%	13%
		57%	18%
3.	Squeira (1999) Total direct cost	21%	13%
4.	Squeira (1999) Cost of wall panels	57%	18%
5.	Al-Tabtabai et al. (1999) Neural network for estimating percentage increase in the cost of a highway project from baseline estimate.		8.1%
6.	Emsley et al. (2002) Total construction cost prediction	20.8-27.9%	16.6%
7.	Kim et al. (2004) Construction cost estimation of residential buildings in Korea	6.95%	2.97%
8	Pewdum et al. (2009) developed an Artificial Neural Network to forecast the final budget and duration of highway construction projects		8.51%
9.	Amusan (2011). Neural network-based cost predictive model for building works.		1.14%
10.	Kim et al. (2013) Compared Estimation Costs of School Building Construction Using Regression Analysis, Neural Network, and Support Vector Machine Methods.	5.68%	5.27%
11.	Petruseva et al. (2013). Neural Network Prediction Model for Construction Project Duration	10.36	2.50
12.	Aibinu et al. (2015) modelled cost of engineering services (power wiring, light wiring and cable pathway) at the design stage. Regression analysis (RA) was unsuitable because the relationship between cost influencing variables and cost of engineering services are subtle and unknown.		6.4, 4.5 and 4.5% predictive errors respectively.
	Relative mean absolute deviation (Rel.MAD)		
	This study		
13.	Cost;	0.70	1.46
	Time;	1.37	0.85

S/No	Author and study	Mean absolute percentage error (MAPE)	
		MLR	ANN
	Previous studies		
14.	Kaur (2016) prepared an ANN model for predicting the duration of the ongoing project		1.70 - 2.60
15.	Gunaydın and Dogan (2004). A neural network approach for early cost estimation of structural systems of buildings.		Average 0.07 Maximum 0.12

6.4 Summary of validation of the developed models

Multiple linear regression impact models were developed with the 9 and 10 identified significant cost and time factors respectively. The conceptualized ANN cost and time impact models were trained with the survey data partitioned into 80:20 i.e. 80% of the data for model trainings and validated with the remaining 20% of the survey data; this same design was used for MLR impact prediction equations. The developed MLR and trained ANN impact prediction models were validated and compared. The MLR models, although better than the ANNs in terms of mean absolute percentage errors and relative mean absolute deviations, provided poor explanations of the variances in the dependent variable (duration impact or time overrun) by the independent variables (influence of the driving factors), and they were found unacceptable. The alternative ANN impact prediction models' statistics are: (i) MAPE of the cost impact model is 6.46% or the developed cost impact model prediction efficiency in this research is 93.54%. The Rel. MAD of the developed cost impact model was computed to be 1.46, in other words, plus or minus 1.46. (ii) MAPE of the duration impact model is 7.06% or the developed duration impact model prediction efficiency in this research is 92.94%. The Rel. MAD of the developed duration impact model was computed to be 0.85 in other words plus or minus 0.85. Moreover, the ANN models compared favourably with previous and similar ANN studies in terms of relative absolute deviations and mean absolute percentage errors. The ANN models are thus better alternatives because of their ability to learn like the human brain and store the knowledge for future project cost and time performance assessments.

CHAPTER SEVEN: SUMMARY OF RESULTS, CONCLUSIONS AND RECOMMENDATIONS

7.1 Introduction

This final chapter recaps the aim and objectives of the study, summarizes the relevant literature and identifies a gap for new research, outlines the key findings from the empirical study, presents the contribution to knowledge, articulates the implications of the research findings and the conclusions drawn, makes recommendations based on the conclusions, identifies the limitations of the study and makes suggestions for future research.

7.2 Aim and objectives of the study

The aim of the research is to examine the impact of construction cost-and-time-influencing factors on the production performance of public building projects in north eastern Nigeria and whether a predictive model could be devised in assessing this impact. The research aim was pursued through the following objectives;

i. Assess the factors influencing the cost and time performance of public building projects in north eastern Nigeria.
ii. Determine the cost and time performance of selected public building projects in the study area.
iii. Conduct a comparative assessment of cost and time performance of selected uncomplicated, moderately complex and largely complex public building projects in the study area.
iv. Examine the impact of project complexity on cost and time performance of selected public building projects in the study area.
v. Develop models for assessing the impact of cost and time influencing factors on cost and time performance of public building projects in the study area.
vi. Validate the developed cost and time performance impact assessment models of public building projects in the study area.

The research commenced with a literature review. Insights into the current trend of construction project performance were gained, together with knowledge of the causation factors of cost and time overruns. A knowledge gap was identified from the literature review and the bridging processes were conceptualized. The research's philosophical assumption of objectivism informed the nature and type of data collected. Consequently, a detailed quantitative data collection instrument (questionnaire) was designed. A sample was collected from the field survey, analyzed with IBM SPSS stastistical version 21, Excel 2016 and Smart Lab software (T395 neural networks). Major findings of the study are divided into the literature review and findings based on empirical data. The findings are discussed in the following sections:

7.3 Summary of gaps in the literature

The insights gained from the review of the literature to this study are summarized as follows.

Poor cost and time performance of construction projects is a global phenomenon: The poor performance of construction projects is experienced in both developed and developing nations. Cost and time overruns are found in all project types. Currently Nigeria does not have an industry-based construction project classification mechanism that classifies construction projects in any way, and there is no global construction project classification in terms of complexity. Adoption of foreign-based classifications do not faithfully represent the actual situation, due to variations in technological advancement, personnel knowledge and experiences, currency value differences, a fluctuating and unstable exchange rate and project site location differences. The foreign based complexity framework adopted in subsection 5.11.1 notwithstanding, the adoptions, conversions and analysis in that subsection were necessitated by lack of a national classification, which would ordinarily describe and factor the local constraints. The computations of years 2003 to 2018 for American and Nigerian data were aimed at mitigating the impact of foreign-based classification, which might not have been completely achieved.

There is a dearth of literature on construction project complexity classifications. There is currently a thin base of literature on construction project complexity classification, this is because project complexity embraces not only the construction cost, duration of constructions, currency value of where project is situated, level and types of plant and machineries, project site coverage and volumes of work, project's geographical location, but also the quantity and quality of off-site and on-site operations, managers and technologists. Current construction project complexity dimensions used by researchers do not capture the human resource quantity and quality dictates of the designs. This also applies to the appropriate plant, machinery and equipment required for various design types and diverse construction locations. There are no known methods of employing construction site personnel that factor in the emotional, mental and general health status of construction site team leaders. For example, construction activities in Nigeria are based more on human labour than on plants and machines. Therefore, the health status of construction leaders and operatives is heavily challenged.

The bulk of cost and time overrun factors are classified under the main contractor's contractual and business responsibilities, making the contractor a stakeholder who should answer major questions regarding construction project cost and delivery time failures. That finding does not align with the results of the study's empirical research. In subsection 7.6.3, data analysis shows that the client takes the major share in construction project cost and time overrun management. It can be inferred from the study result that responsibility in the management and control of construction project cost and time slippages rest mainly on the client, who is the party who initiates the project type and project policies, settles all bills, and is the leader of all teams on the construction project.

Some cost and time factors have a double influence on both project cost and scheduled delivery targets. The analysis in the literature found 53% to 60% of the drivers under both cost and time constructs. The empirical aspect of this study confirmed the double influence characteristics. Five influence factors have been identified: cash flow problems, delays in payments to the main contractor, inadequate prime cost and provisional sum, variations to work and contract information delay. These factors are between 55.56% (5/9 * 100) and 50% (5/10 * 100) of the significant cost and time factors.

There is a paucity of studies on some aspects of construction cost and time performances, which are currently summarised in the theory of cost overrun. Existing volumes of research efforts tend towards finding the causes of cost and time overruns, with little effort on the overrun prediction studies that equip projects for precautionary measures ahead of time. Details of the theory include how cost overruns behave over time in terms of frequency and magnitude, and several important issues like how the cost overruns vary with the size, types of projects, locations and contractors. An outline of Jain and Singh's (2012) cost overrun theory are: (i) cost overrun declines over time (ii) cost overrun is relatively high for procurement involving construction projects compared to procurement of finished products such as machinery, within construction projects, (iii) more complex projects experience higher cost overruns than less complex ones. Lastly (iv) in contrast to the existing literature, there is an increase in the probability of contractors asking a for higher price in the renegotiation of incomplete and revitalization contracts.

There is a dearth of research about the north eastern Nigerian construction and project management sector. The situation is compounded by the Boko Haram insurgency, currently disturbing the smooth and full-scale construction activities in the zone. Before the outbreak of insurgency activities in 2003, Nigeria's north-east geopolitical area suffered more from paucity of engineering indigenous and foreign academic research into the built environment. The Boko Haram insurgency further compounded the underdeveloped geopolitical zone construction management research-wise.

The tool, MLR, hitherto used by construction resource estimators (Chou and Tseng, 2011; Kim et al., 2004; Merrow et al., 1988; Tam and Fang, 1999) is weak in terms of its ability to forecast construction cost and duration. In line with other researchers such as Adeli and Wu (1998), Bode (1998) and Bode (2000), Garza and Rouhana (1995), Kim et al. (2004), Smith and Mason (1997), Tam and Fang (1999), this study discovers MLR's inappropriateness in mapping completely the construction project multiple input variables needed in the design of cost and duration impact prediction models.

The inadequacies of the pioneer time-cost relationship model have been apparent in other research. Many researchers have queried the inclusion of cost as an independent variable in the Bromilow (1969) time-cost model. Some others argued on the geographical limitations while some modified the model to suit their local environmental settings and many scholars confirmed the model's relevance to their own locality. There are authors who only confirmed the model's suitability to some types of projects in their own locality. Several MLR forecasting models had, therefore, resulted from previous research across the globe, aimed at proffering solutions to the challenges of cost and time overruns. The non-reduction of these overruns translates as the ineffectiveness of cost and duration tools hitherto used in the industry (Gurnick, 1975). Observers, critics and researchers into construction project cost and time performances have therefore for called for a paradigm shift to a machine learning system for construction resource forecasting. This is the introduction of an artificial intelligence (AI) system into project management techniques for construction resources estimating, assessments and management.

A synthesis of MLR and ANN shows the similarities between the two techniques (White et al., 1992). The same input and output variables are fed into MLR mathematical model and ANN network model in project management practice. The ANN model performs internal adjustments to the synastic weights while training to create a live-model (the human brain simulations) giving a state of the act answer(s) to problems. The MLR model does no adjustments but remains static to produce solutions that do not correctly fit research problem(s) set.

Successes in the use of artificial neural networks are being recorded in the use of ANN in construction project management in developed economies. Not much has been known about ANN in the developing countries' construction industry. The study being reported took advantage of the call for a paradigm shift, drew inspiration from past research in the artificial neural network (ANN) technique in construction project management, to embark on research, the results of which shall make contributions to knowledge in the aspects of construction economics and management generally, and particularly in construction project cost and time assessments.

There are fallow research issues on the field of construction management in the study area. The study area, compared with other geopolitical zones in Nigeria, lacks research into the challenges in construction project cost and time performance assessments, as they affect the societies and local communities in the zone.

7.4 Summary of findings based on analysis of empirical research

This section presents the findings from the empirical research. The findings are presented below on each objective, research question and hypotheses.

7.4.1 Objective 1

Assess the factors influencing the cost and time performance of public building projects in north eastern Nigeria

Analysis of data on the 43 factors identified from literature shows the following nine (9) cost driving factors; contract manager's inexperience (2.96), payment delays to the main contractor (2.85), unstable foreign exchange (2.80), variations to works (2.72), fraud/corrupt practices (2.66), government's changes in policy and fiscal measures (2.65), inadequate prime cost and provisional sum (2.64), cash flow problems (2.63) and contract information delay (2.63) affect construction projects in Nigeria's north-east geopolitical zone.

From the group mean scores, the ten (10) time influence factors that affect construction programmes in the study area; design errors (2.81), cash flow problems (2.72), payment delays to the main contractor (2.68), inadequate prime cost and provisional sum (2.66), delay in drawing preparations and approval (2.63), contractors' inadequate contract knowledge

(2.62), natural disasters such as floods (2.61), non-performance of subcontractors (2.61), design changes (2.60) and variations to works (2.59).

7.4.2 Objective 2

Determine the cost and time performance of selected public building projects in the study area.

The study found a 49% variability between construction project initial contract sums and final cost. There are no statistically significant differences in cost overruns in between locations in the study area (Adamawa North, Adamawa South, Bauchi State, Gombe State and Taraba States).

The study found a 55% variability between the estimated and actual construction duration. Like the cost variability, there are no significant statistical differences in time overruns between locations in the study area.

7.4.3 Objective 3

Conduct comparative assessment of cost and time performance of selected uncomplicated, moderately complex and largely complex public building projects in the study area

The results showed that the construction cost performance between small or uncomplicated and medium or moderately complex projects was not significant, while it was significant between small or uncomplicated and large or complex projects. Between medium or moderately complex and large or complex projects, the construction cost performance was also significant.

Construction time performances between small or uncomplicated and medium or moderately complex as well as large or complex projects were found to be significant. The time performance between medium or moderately complex and large or complex projects was however, not significant.

7.4.4 Objective 4

Examine the impact of project complexity on cost and time performance of selected public building projects in the study area.

It was found in the study that, there is a statistically significant difference in the project complexity cost impact performance between small or uncomplicated and large or complex construction projects. The same was also found of the complexity impacts on cost performance of the medium or moderately complex and large or complex projects. The mean cost performance impact differences between small or uncomplicated and medium or moderately complex construction projects was found not to be significant.

Project complexity impact on time performance, which showed differences across the three classes of construction projects, were found not to be significant.

7.4.5 Objective 5

Develop model for assessing impacts on cost and time performance of public building projects in the study area.

Two types of construction cost assessment models were developed in the research, one from multiple linear regression (MLR) analysis and the other from the artificial neural network (ANN) model. The ANN models on validation were found as better alternatives to MLR due to their ability to capture the multiplicity of input variables, which are the cost driving factors.

Two types of construction time assessment models were developed in the research, one from multiple linear regression (MLR) analysis and the other from the artificial neural network (ANN) model. The ANN models on validation were found as better alternatives to MLR due to their ability to capture the multiplicity of input variables which are the time driving factors.

7.4.6 Objective 6

Validate the developed cost and time performance impact assessment models of public building projects in the study area.

The developed ANN impact prediction models were validated with 20% of survey data reserved for the purpose. The MLR models, although better than the ANNs in terms of mean absolute percentage errors and relative mean absolute deviations, had poor explanations of the effect of independent variables on the dependent variables. The alternative ANN impact prediction models' statistics are; (i) MAPE of the cost impact model is 6.46%, or the developed cost impact model prediction efficiency in this research is 93.54%. The Rel. MAD of the developed cost impact model was computed to be 1.46, in other words plus or minus 1.46. (ii) MAPE of the duration impact model is 7.06%, or the developed duration impact model prediction efficiency in this research is 92.94%. The Rel. MAD of the developed duration impact model was computed to be 0.85, in other words plus or minus 0.85. The ANN models compared favourably with previous similar studies in terms of relative absolute deviations and mean absolute percentage errors.

7.4.7 Cost and time factor analysis by factor reductions

Based on their weak loadings in the Pattern, Structure Matrices and Communalities 25 factors each were shed from the cost and time constructs based on their weak loadings in the Pattern, Structure Matrixes and Communalities loadings in the factor analysis. This is a lesson reflecting on the position of objectivism this research aligns with, that knowledge is not created but only must be discovered.

The 43 cost drivers by factor were reduced to five componts. The components include: (i) payments and information supply delays by clients, payment delays to subcontractors and suppliers, payment delays to the main contractor, contract information delay, and inadequate prime cost and provisional sum; (ii) price galloping and inaccurate estimates - fluctuations/inflation of prices, and inaccurate cost estimates; (iii) design errors by consultants and cash traps by clients — design changes, changes in specifications, design errors, and cash flow problems; (iv) the 7-point all-inclusive cost drivers — lack of co-ordination of project parties, improper contract knowledge by contractors, industrial unrest/strikes, and unseen site/soil conditions, delays in the delivery of imported materials, inadequate project monitoring, and fuel shortages; (v) takeholder-related challenges— non-adherence to contract conditions by the stakeholders.

Similarly, the 49-time drivers were reduced to seven components; (i) The 3-winged bird of industrial unrest/strikes, delay in the delivery of imported materials and a fuel crisis; (ii) The Boko Haram related factors, comprising political-religious instability, civil commotion and community issues – these also affect lack of relevant tools and equipment, insecurity/insurgency, and force majeure. (iii) Client's red-tapism and lack of technical know-how - bureaucracy in client's organization, client's slowness in decision making, and incomplete technical documentations. (iv) Project contractor's draw-back and natural disaster - delay in building permits approval, inadequate planning and scheduling, natural disaster such as a flood, contractor's inexperience, and poor site management and supervision. (v) Client's sole responsibility - variations to works, and design changes. (vi)Contractor, project complexity and client issues - cash problems, poor labour productivity, project complexity and lack of communications between parties (vii) the trouble-shooting factors - rework due to mistakes, and conflict between contractual parties.

7.4.8 Dual influences of some construction cost and time factors

The dual influence nature of some construction cost and time driving factors was first established in previous studies in sections 2.5.3 and 2.5.4 in Chapter Two and section 3.5 Chapter Three. It can be seen in the analyses of construction cost and time significant factors in section 5.4 that five factors are replicated on both constructs, these are payment delays to main contractors, inadequate prime cost and provisional sum, cash flow problems and variation to works. The research results show that these factors are between 50.56% - 55.00% of factors in both cost and time constructs.

7.5 The contributions to knowledge

The research results have contributed to knowledge in the construction management knowledge area. They highlighted the double influence characteristics of some construction stage influence factors. The study also reveals in Appendix XXXII, five of the significant factors that act simultaneously (influencing both cost and time targets). It leads to the call that studies in construction project performance be made in the same research instead of separate cost and time studies.

The study added to knowledge on the inappropriateness of multiple linear regression in the modelling of the relationships between the construction stages multiple costs and time influence factors, and their impact on the final cost and actual construction durations. It adopted artificial neural network (ANN) into the assessment of construction cost and time performance assessments and developed impact models for assessing cost and time overruns for construction projects. The use of the developed models will serve as a better alternative to the percentage addition methods hitherto called contingencies, the measure aimed at absorbing overruns.

The research provided basic information on the cost and time performance differentials in uncomplicated, moderately complex and largely complex projects as well as project complexity impact differentials for industrial consumption in the study. The study has also put Nigeria, particularly the north-east geopolitical zone on the world map of quantitative information provisions on the theory of not only cost but time overrun.

On construction project time performance, the study results contributed to existing knowledge as it revealed a group of similar factors, civil society/community issues, insecurity and insurgency, covered under the umbrella name of Boko Haram as a major factor contributing to late delivery of construction projects in the study area.

7.6 Practical implications of the research findings

The study results bear practically on the design and management of construction projects in the following dimensions.

7.6.1 Artificial neural network models construction project cost and time management tools

Effective use of ANN impact models hopefully would dispel the notion of the intractability of the persistent cost and time overrun challenges (Jennings 2012; Jarkas 2016) due to the multiplicity of the causation factors. The developed impact assessment models may be useful tools to government agencies like the Bureau for Public Procurement (BPP) in Nigeria in the provision of services. Such models could also be developed for other countries on the continent, using data generated from previous and similar but recently completed construction projects, for example data on complex construction projects in the Western Cape, for the development of construction cost and time performance models for Cape Town, South Africa.

7.6.2 Information provision to foreign investors

Some of the results of this study provide information relevant to contruction business investors who are interested in setting up construction companies, and who might need such information for strategic planning in the study area.

7.6.3 Responsibilities of the contractual parties for the management of cost and time driving factors

The nine (9) and ten (10) significant factors determined with the Pareto rule shown in Appendix XXXII are separated into the contractual parties responsibilitíes, using Kim et al. ’s (2008) classifications. On the cost variables, the key project stakeholders by frequency are client (5 factors), consultant (3 factors) and contractor (3 factors).

Similarly, on the time variables by frequencies; client and consultants have 5 factors each and the contractor has 2 factors. These imply that key stakeholders share in a descending order of responsibility for construction cost and time factors’ management as follows; client→consultant→contractor**.** The research findings do not uphold those of Ogunlana et al.

(1996), Abd-Majid and McCaffer (1998) and Aljohani et al. (2017) who found that most of the causes of time overrun are related to poor construction programme management by the project contractor. Thus, the significant construction cost and time influencing factors comprise mainly the activities of first the client, followed by the consultants, and then those of the contractor.

7.7 Conclusions and recommendations

This research modelled cost and time performance of public building projects in Nigeria's north-east geopolitical zone. Terms that aid the understanding of the research problems were defined and explained in the literature review Chapter Two, together with a global outline of poor performance of construction projects and the causal factors. The main research question was coined from the identified current gap in knowledge which was spelt out in Chapter Three. Answering the research questions formed the basis of the design of the research instrument, the data collection procedures and methods of analysis. These spread through chapters three, four, five and six. The following conclusions are based on the findings drawn from the literature review and empirical research. Though researchers and estimators are not unaware of the weaknesses and inappropriateness of the MLR modelling technique, its relevance to construction resources forecast still cannot be downplayed. Multiple linear regression analysis compares favourably to other feature-based approximate or preliminary estimating methods as superficial or area, cubic metre and storey-enclosure methods. MLR's relevance in establishing project-base cost for subsequent detailing in the bills of quantities can hardly be replaced. However, this research provides additional results to the studies that observe the limitations of the MLR technique in mapping the relationship between overruns and the multiple cost and time driving factors.

The construction contract sum detailed in the bills of quantities can best be assessed for cost and completion duration at the construction stage, using the ANN impact assessment model rather than MLR. Neural networks learn from examples, and so the performance of a neural network model for cost and duration estimation strongly depends on the quality and the number of examples used in training the network model. A higher quantity of input and output data reduces the prediction error of the designed model. Thus, to study modelling and prediction methods, and construct an efficient and effective prediction model of building cost and time overruns, there is a need for reliable, high-quality, full-scale cost and time data of buildings of various types and conditions. The models of this research have established a methodology that can provide an economical and rapid means of assessing cost and time overruns on the estimated bills of quantities and construction programmes for future building projects at any stage of the construction process. The ANN capability of seizing knowledge by examples and not by rules represents a very interesting and innovative factor in terms of construction project performance assessment. The developed ANN models aid the construction contractor to predict cost and time overruns caused by the influence of construction stage cost drivers on the bills of quantities baseline contract sum, and the overall programme of construction duration. The ANN approach broadens the possibility of building a full-scale knowledge-based model for predicting the individual cost and time overrun sensitivity of construction activities on the entire building cost and construction programme.

Based on the conclusion drawn from the findings and limitations encountered during the research, the following recommendations are made;

- The reason for the insurgency is ‘the unrighteous stand of people in Islam’ due to the quest for western education, which the sect claims ought to be forbidden. And from the sect’s level of commitment to their ideas, in terms of arms and ammunition, and the enormous destruction of lives and property for the past 16 years (2003 to 2018), why is the Federal government of Nigeria not seeing reasons to get close to the group and embark on a dialogue? Why should the nation continue to spend on armaments, and waste the lives of Nigerian soldiers to an unknown end? Questions of interest should be: Are there any merits in what the Boko Haram sect is claiming? What could it be in the western style of education that is regarded as inimical to proper Islamic growth and development in Nigeria alone? The Nigerian ruling class should view the Boko Haram activities as beyond mere acts of criminality, political lawlessness or radicalism. Federal government should devise ways to meet with the sect with the aimof reaching a common ground for peaceful co-existence by all citizens in all parts of Nigeria, irrespective of religious differences.
- Templates are recommended for use in the documentation of the complexity levels of construction projects; personnel and equipment-wise, as attached in the Appendices XXVI and XXVII.
- Project managers, contractors, quantity surveyors, architects, builders and engineers should prioritise the significant factors identified in this study in their project planning, monitoring and control activities.
- The developed impact assessment models obviously have several potential applications in industry and construction management practice. Their conversion to dashboard packages that construction professionals could use in rapid prediction of cost and time overrun of construction projects, using the significant factors at all stages of the project, is therefore recommended.
- To address the current unorganized method of construction project information record keeping in Nigeria. The author believes that using recorded quantitative data on construction cost and time influence factors for construction projects performance modelling should be more scientific than evidence from project stakeholders supplied in ordinal measurement scales. Adequate record keeping which is currently not available in any form in Nigeria is vital to ensure availability for research purposes. Complete recordings of all public procurement should be made mandatory at all the tiers of government in Nigeria. This will enhance research in construction economics and management, reduce the challenges as well as make research results much more reliable. On that note, research and development will contribute meaningfully to the nation's economy. For example, in Clark County Public Works Department, Las Vegas, NV 89154, USA, archiving of project data is done by scanning all the project documents and drawings into the Global 360 KoVIS database. The paper copies are then destroyed, due to shortages in physical storage space. To retrieve the data for

each project, specific information is required. Each project can be accessed either by project numbers or by bid numbers. Shrestha et al. (2013) used bid number to retrieve the data used in their study.

7.8 Research limitations

Challenges were encountered due to the confidential nature of the data required for the study; these included difficulties in receiving responses from respondents. Except for archival data, human memories in recalling exact occurrences of problematic issues on cost and construction programme tracking may have impacted negatively on the quality of data used in the analysis of this study. That also could limit the expected precision of the models' usage. The questionnaire was bulky from the size of the third and fourth sections which solicited data on a total of 92 cost and time variables. Respondents found the time spent filling the questionnaire boring. This hindered many respondents from participating. Issues on Boko Haram insurgency in north eastern Nigeria limited the spread of data sourcing to places less affected, in the study area.

7.9 Future research

- Comparison of the significant cost and time factors in Appendices XXX and XXXI shows variations of the factors and order of significance by methods of derivation. These are motivations for future studies.
- Moreover, the results of the study on the dual influence of some factors on both construction cost and time are a motivation for further research on the theory of the symbiotic or compensational relationship, in terms of the influence of project cost and time driving factors.
- Future deeper investigations on the impact of insurgencies on construction projects cost and time performance in the Nigeria north-east geopolitical zone can be conducted as a follow-up to this study. Results of such studies shall add to the documentations of losses incurred from the Boko Haram insurgencies in the study area.

7.10 Chapter Summary

The chapter emphasized the need for further studies with artificial neural network modelling of the various sectoral building types in the study area. It called for future studies that would focus on the impacts of Boko Haram insurgency on building construction cost and time performance in the study area, and further research into other sections of construction cost overrun theory not covered in this report.

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APPENDIX I: Ethics Signature Form

Application for Approval of Ethics in Research (EiR) Projects
Faculty of Engineering and the Built Environment, University of Cape Town

APPLICATION FORM

Please Note:
Any person planning to undertake research in the Faculty of Engineering and the Built Environment (EBE) at the University of Cape Town is required to complete this form before collecting or analysing data. The objective of submitting this application prior to embarking on research is to ensure that the highest ethical standards in research, conducted under the auspices of the EBE Faculty, are met. Please ensure that you have read, and understood the **EBE Ethics in Research Handbook** (available from the UCT EBE, Research Ethics website) prior to completing this application form: http://www.ebe.uct.ac.za/usr/ebe/research/ethics.pdf

APPLICANT'S DETAILS		
Name of principal researcher, student or external applicant		OBOIRIEN, MOMOH OHIOMAH
Department		CONSTRUCTION ECONOMICS & MANAGEMENT
Preferred email address of applicant		oboirienmomoh@yahoo.com
If a Student	Your Degree e.g., MSc, PhD, etc.	PhD
	Name of Supervisor (if supervised)	Prof. ABIMBOLA OLUKEMI WINDAPO
If this is a researchcontract, indicate the source of funding/sponsorship		Not Applicable
Project Title		MODELING COST AND TIME PERFORMANCE OF PUBLIC BUILDING PROJECTS

I hereby undertake to carry out my research in such a way that:

- there is no apparent legal objection to the nature or the method of research; and
- the research will not compromise staff or students or the other responsibilities of the University;
- the stated objective will be achieved, and the findings will have a high degree of validity;
- limitations and alternative interpretations will be considered;
- the findings could be subject to peer review and publicly available; and
- I will comply with the conventions of copyright and avoid any practice that would constitute plagiarism.

SIGNED BY	Full name	Signature	Date
Principal Researcher/ Student/External applicant	Mr. MOMOH OHIOMAH OBOIRIEN		11 Feb 2017

APPLICATION APPROVED BY	Full name	Signature	Date
Supervisor (where applicable)	A/Prof. Abimbola Olukemi Windapo		13 Feb 2017
HOD (or delegated nominee) Final authority for all applicants who have answered NO to all questions in Section1; and for all Undergraduate research (Including Honours).	Click here to enter text.		Click here to enter a date.
Chair : Faculty EIR Committee For applicants other than undergraduate students who have answered YES to any of the above questions.	G. Sithole Click here to enter text.		26/03/2017 Click here to enter a date.

APPENDIX II*: Researc participants' consent form*
UNIVERSITY OF CAPE TOWN

IYUNIVESITHI YASEKAPA ●UNIVERSITEIT VAN KAAPSTAD

Department of Construction Economics & Management,
Level 5, Snape Building,
Upper Campus,
University of Cape Town (UCT),

P. M. B. X7,
Rondebosch 7701,
South Africa.

To whom it may concern:

Dear Sir/Madam,

<u>MODELING COST AND TIME PERFORMANCE OF PUBLIC BUILDING PROJECTS</u>

This Doctoral research examines the changes in construction contract cost/time (overruns) and factors responsible for these changes, with a view of generating models for predicting final construction cost and duration at pre-contract stage of projects. The researcher invites you to participate in the study by virtue of your position in the institution/organisation and your level of experience in the management of building and infrastructural construction and maintenance.

Three forms are attached herewith (Type A.1, Type A.2 and Type B) for data mining on some of your recently completed building projects (between 2010 and 2016). Type A.1 is for data extractions on the buildings comprising owner institution and department, the use, tender sum, final construction cost, year developments commenced and completed. Completion of Type A.2 will enable the researcher to locate the external project stakeholders (Consultants, Contractors, Suppliers and others) who will complete the structured questionnaire (Type B) designed for gathering experiential evidence on sites pertaining to all that transpired during project execution regarding additional costs, time extensions, and delays. A copy of Type B data mining guide is attached to this survey for your notification only.

The researcher promises that any information supplied shall be treated in strict confidence; no names shall be included in the thesis report but identification number only. Data collected shall be presented in aggregate form, sources are known only to the researcher and supervisors whose names are highlighted below. These data shall neither be shared with anybody nor attributed to any names and identifications will not be used in any publications or presentations. The researcher shall safeguard and dispose of data collected after by the research exercise.

Kindly note that your participation in the research is entirely voluntary; there are no adverse consequences if you choose not to participate. If you choose to participate but, wish to withdraw at any time, you will be free to do so without negative consequences.

You may by chance share some personal or confidential data especially with researches having to do with construction project cost, the researcher promises to prevent any risk that could arise as earlier stated, and such data after being destroyed shall not be available for use as evidence against participants. Please note that there are no benefits to be obtained by your participation. However, knowledge gained shall be beneficial to the construction industry.

A summary of the research results will be sent to you on request.

<u>Declaration</u>

I…………………………………………………………………………this……………day of………………..
2017 acknowledged that the researcher has explained my rights as a respondent, the requirements of this study and minor risks involved in participating in the study. Also I understand the absence of compensations or direct benefits to me as an individual. With my signature and contact information below, I indicate that I consent to participate in the study and being above eighteen (18) years of age, I am eligible to take part in the exercise.

Signature………………………………………………………….. Date…………………….

Designation………………………………………………….

Email Address………………………………………………….

Mobile Phone Number…………………………………………

Name of Your Institution/organization…………………………………………………………

………………………………………………………………
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APPENDIX III: Letter of introduction to Adamawa state University, Mubi

Building Department,
Modibbo Adama University of Technology,
Yola.
21/08/2017.
+2348064326749
Email: oboirienmomoh@yahoo.com

To:
Vice Chancellor,
Adamawa State University,
Mubi.

Through,
Registrar,
Adamawa State University,
Mubi.

Through;
Head of Department,
Building Department,
Modibbo Adama University of Technology
Yola,
Adamawa State.

This is confirm the undersigned is our staff and on research kindly give him the necessary information, which I believe will be handled with research norm of confidentiality.

21

Sir,

Ph.D. RESEARCH: REQUEST FOR BUILDING PROJECT PERFORMANCE DATA

I am an academic staff from the department of Building, Modibbo Adama University of Technology, Yola researching on the topic; *Modelling Cost and Time Performance of Public Building Projects* in the University of Cape Town, South Africa. My study centre is Tertiary Institution Buildings in Nigeria's North-East Geo-Political zone.

Please kindly give me access to historical data on the University's completed building and infrastructure projects, to enable me proceed with the study. The needed data shall be required in the following format;

S/No	Building/Civil Engineering Project		Construction Cost and Duration Performance			
	Procurement System	Use e.g. Lect.Theatre, Library, etc.,	Cost		Duration	
			Tender Sum	Final Account	Initial Construction Duration	Actual Construction Duration
1.						

APPENDIX IV: Data sourcing instrument

UNIVERSITY OF CAPE TOWN
IYUNIVESITHI YASEKAPA ●UNIVERSITEIT VAN KAAPSTAD

Department of Construction Economics & Management,
Faculty of Engineering and the Built Environment,
University of Cape Town,
Rondebosch 7701,
Cape Town, South Africa.
FEBRUARY 2017.

Dear Madam/Sir,

MODELLING COST AND TIME PERFORMANCE OF PUBLIC BUILDING PROJECTS

This questionnaire is part of a PhD (Construction Economics and Management) research thesis that is examining the impact of construction cost and time influencing factors on final duration and cost of construction projects.

The phase of the research process is aimed at sourcing project's stakeholders' evidential data on the identified project during constructions. The questionnaire can be completed in 12 minutes. Please feel free to add or make further comments that will improve the results of the study. The information provided will be treated in strict confidence. Should you have any question(s), do not hesitate to contact the undersigned on +234 8064326749 or send email to oboirienmomoh@yahoo.com

Thank you for your assistance.

Oboirien M. O. **Dr. Abimbola Windapo** **Prof. Henry Odeyinka**
(PhD Candidate) **(Supervisor)** **(Co-Supervisor)**
oboirienmomoh@yahoo.com

A SURVEY OF COST AND TIME INFLUENCING FACTORS IN PROJECT DELIVERY

Please answer the following by supplying the information and ticking the relevant options based on a project recently completed of which you are a part of the construction team.

Section 1: Participant's Personal Information

Please tick one of the options provided

B.1) Profession: 1. Architect □ 2. Builder □ 3. Civil/Structural Engineering □ 4. Quantity Surveying □ 5. Services Engineering (Mech./Electrical) □

B.2) Academic qualification: *(Please tick highest that applies)*

1. ND □ 2. FTC (City & Guilds Full Technological Certificate) □ 3. HND □ 4. B.Sc./B.Tech □ 5. M.Sc. □ 6. PhD. □

B.3) Post Qualification Experience

Up to 5 years □
6-10 years □
11-15years □
16-20 years □
20 years and above □

B.4 Membership of professional association?

1. MNIA/FNIA □2. MNIOB/FNIOB □ 3. MNSE/FNSE □
4. MNIQS/FNIQS □ others (Please specify): ……………...

B.5 In which of the following capacity did you serve on the project?

1. Client □ 2. Consultants □ 3. Main contractor □ 4. Supplier □ 5. Sub-contractor □

B.6 What was your official designation on the project?

1. Consultant Architect □ 2. Consultant Civil/Structural Engineer □ 3. Consultant Quantity Surveyor □ 4. Resident Builder □ 5. Consultant M & E 6. Site Agent □ 7. Construction Manager □ 8. Site Manager □ 9. Site Engineer □ 10. Site Quantity Surveyor 11. Site Supervisor □ 12 Others □

Section 2: Project Information

Please recall and provide the following from your completed project records

B.7 Project Name (Optional)………………………………………………………………….
B.8 Location (State where located) ……………………………………………………………….
B.9 Initial Contract Sum: ₦……………………………………………………………………
B.10 Final Account: ₦……………………………………………………………………….
B.11 Estimated completion duration… ……………………………………. Months
B.12 Actual completion duration: …………………………………………. Months
B.13 Building type:

1. Administrative □ 2. Block of classrooms □ 3. Theatre □ 4. Hostel/Hall of residence □ 5. Shopping complex □ 6. Laboratory □

B.14 Procurement Method:

1. Traditional procurement □; 2. Fixed/Firm Price Contract □ 3. All-in Service/Package Deal □ 4. Cost Reimbursement/Target Cost Contract □ 5. Turnkey 6. Two-Tier Contract System □ 7. Management Contracting □; 8. Construction Management □ 9. BOOT □

Section 3. Cost Performance Influence Factors on Construction Projects

The following is a list of factors thought to influence the cost performance of construction projects. Based on your nominated project, please score on a scale of 0 – 5 the level of influence on cost of the factors during the execution of your project where 0-represents no influence on cost; 1 very low influence on cost; 2-low influence on cost; 3 moderate influence on cost; 4-high influence on cost; 5 very high influence on cost.

S/No	Cost influencing factors	Scale of Influence					
		None 0	V. Low 1	Low 2	Moderate 3	High 4	V. High 5
BC.1	Fluctuations/inflation of prices						
BC.2	Inaccurate cost estimates						
BC.3	Contractors' poor cost/financial management						
BC.4	Poor cost control systems						
BC.5	Lack of relevant information and details						
BC.6	Non-adherence to contract conditions						
BC.7	Discrepancy/deficiency in contract documents						
BC.8	Shortage of materials						
BC.9	Government's changes in policy and fiscal measures						
BC.10	Delay in equipment supply						
BC.11	Low-quality materials						
BC.12	External parties' influence						
BC.13	Unstable foreign exchange						
BC.14	Changes in material specification						
BC.15	Weak regulation and control						
BC.16	Economic insecurity						
BC.17	Unstable and high-interest rate						
BC.18	Variation to works						
BC.19	Inadequate prime cost and provisional sum						
BC.20	Contract information delay						
BC.21	Payment delays to the main contractor						
BC.22	Payment delays to sub-contractor and supplier						
BC.23	Contract manager's inexperience						
BC.24	Changes in specifications						
BC.25	Design changes						
BC.26	Design errors						
BC.27	Contractor's inability to manage risks and Uncertainties						
BC.28	Poor labour productivity						
BC.29	Cash flow problems						
BC.30	Project complexity						
BC.31	Lack of communication between parties						
BC.32	Non-performance of sub-contractors						

S/No	Cost influencing factors	Scale of Influence					
		None 0	V. Low 1	Low 2	Moderate 3	High 4	V. High 5
BC.33	Conflict between contractual parties						
BC.34	Rework due to mistakes						
BC.35	Shortage of labour						
BC.36	Fuel shortage						
BC.37	Industrial unrest/strikes						
BC.38	Delays in the delivery of imported materials						
BC.39	Unforeseen site/soil conditions						
BC.40	Lack of coordination of project parties						
BC.41	Inadequate project monitoring						
BC.42	Contractors' improper contract knowledge						
BC.43	Fraud/corrupt practices						

Section 4: Time Performance Influence Factors in Construction Projects

The following is a list of factors thought to influence the time performance of construction projects. Based on your nominated project, please score on a scale of 0 – 5. the level of influence on time of the factors during the execution of your project where 0-represents no influence on time; 1 very low influence on time; 2 low-influence on time; 3 moderate influence on time; 4-high influence on time; 5 very high influence on time.

S/No	**Time influencing factors**	**Scale of Influence**					
		None 0	**V. Low 1**	**Low 2**	**Moderate 3**	**High 4**	**V. High 5**
BT.44	Site accident						
BT.45	Incomplete technical documentations						
BT.46	Bureaucracy in client's organization						
BT.47	Client's slowness in decision making						
BT.48	Client's undue interference						
BT.49	Delay in drawing preparations and approval						
BT.50	Poor site management and supervision						
BT.51	Contractor's inexperience						
BT.52	Delay in inspection and testing of completed work						
BT.53	Inadequate planning and scheduling						
BT.54	Delay in building permit approval						
BT.55	Natural disaster such as flood						
BT.56	Force majeure						
BT.57	Civil commotion/community issues						
BT.58	Political instability						
BT.59	Insecurity/insurgency						
BT.60	Lack of relevant tools and equipment						
BT.61	Obsolete/unsuitable construction equipment						
BT.62	Poor project management						
BT.63	Unclear and inadequate instructions to operators						
BT.64	Programme/Schedule delay						

BT.65	Inclement weather
BT.66	Poor construction programme management
BT.67	Variation to works
BT.68	External parties' influence
BT.69	Inadequate prime cost and provisional sum
BT.70	Contract information delay
BT.71	Payment delays to the main contractor
BT.72	Payment delays to sub-contractor and supplier
BT.73	Contract manager's inexperience
BT.74	Changes in specifications
BT.75	Design changes
BT.76	Design errors
BT.77	Contractor's inability to manage risks and Uncertainties
BT.78	Poor labour productivity
BT.79	Cash flow problems
BT.80	Project complexity
BT.81	Lack of communications between parties
BT.82	Non-performance of sub-contractors
BT.83	Conflict between contractual parties
BT.84	Rework due to mistakes
BT.85	Shortage of labour
BT.86	Fuel shortage
BT.87	Industrial unrest/strikes
BT.88	Delays in the delivery of imported materials
BT.89	Unforeseen site/soil conditions
BT.90	Lack of coordination of project parties
BT.91	Inadequate project monitoring
BT.92	Contractors' improper contract knowledge

APPENDIX V: The surveyed construction projects

Project ID No	Project complexity Class	Initial contract sum (Nm)	Final cost (Nm)	Percentage cost overrun (%)	Project ID No	Estimated construction duration (Wks)	Actual construction duration (Wks)	Percentage time overrun (%)
130	Small	83.2	108.6	31	92	8	48	500
207	Small	101.5	103.8	2	181	8	40	400
154	Small	104	114	10	164	10	28	180
117	Small	110	315	186	23	12	20	67
232	Small	120	190	58	73	12	48	300
236	Small	120	140	17	78	12	72	500
244	Small	122	138	13	80	12	24	100
241	Small	132	139	5	89	12	44	267
1	Small	139.96	195.92	40	235	12.5	14	12
234	Small	152	173	14	97	14	32	129

Project ID No	Project complexity Class	Initial contract sum (Nm)	Final cost (Nm)	Percentage cost overrun (%)	Project ID No	Estimated construction duration (Wks)	Actual construction duration (Wks)	Percentage time overrun (%)
235	Small	164	173	5	52	15	25	67
153	Small	171	211.5	24	217	15	33	120
246	Small	178	200	12	228	15	40	167
238	Small	180	280	56	29	16	50	213
233	Small	192	309.8	61	98	16	27	69
211	Small	193	401	108	184	16	20	25
147	Small	200	400	100	211	16	48	200
159	Small	200	400	100	236	16	20	25
69	Small	200	313	57	53	17	28	65
142	Small	200	300	50	61	17.5	35	100
150	Small	210	218	4	99	18	40	122
115	Small	212.5	325	53	11	20	42	110
243	Small	250	261	4	40	20	40	100
15	Small	265	292	10	50	20	45	125
239	Small	295	330	12	64	20	22	10
97	Small	300	800	167	86	20	56	180
98	Small	300	410	37	137	20	20	0
196	Small	320	380	19	207	20	22	10
230	Small	340	450	32	234	20	22	10
102	Small	350	521	49	57	21	60	186
134	Small	350	450	29	9	24	28	17
179	Small	350	346	-1	14	24	96	300
10	Small	367.27	541.27	47	21	24	32	33
12	Small	400	700	75	31	24	36	50
84	Small	400	700	75	54	24	30	25
7	Small	400	510.81	28	62	24	36	50
133	Small	410	616	50	72	24	32	33
129	Small	415.6	713.2	72	84	24	44	83
121	Small	418	519	24	101	24	32	33
30	Small	420	700	67	117	24	40	67
245	Small	420	512	22	131	24	40	67
46	Small	420	450	7	161	24	36	50
104	Small	432	500	16	214	24	36	50
143	Small	436	1218	179	216	24	32	33
210	Small	453.3	814.7	80	219	24	48	100
113	Small	455	612	35	83	25	30	20
70	Small	460	450	-2	232	26	28	8
67	Small	470	535	14	75	28	32	14
178	Small	500	900	80	111	28	36	29
40	Small	500	800	60	115	28	64	129
25	Small	500	709	42	129	28	36	29
68	Small	500	630	26	204	28	48	71

Project ID No	Project complexity Class	Initial contract sum (Nm)	Final cost (Nm)	Percentage cost overrun (%)	Project ID No	Estimated construction duration (Wks)	Actual construction duration (Wks)	Percentage time overrun (%)
149	Small	500	580	16	230	28	40	43
145	Small	501	685	37	2	30	60	100
125	Small	510.2	616	21	60	31	64	106
128	Small	554	705	27	38	32	48	50
22	Small	560	575	3	48	32	40	25
13	Small	600	1600	167	66	32	36	13
62	Small	600	1600	167	74	32	40	25
139	Small	600	882	47	103	32	44	38
116	Small	611	810	33	114	32	64	100
64	Small	612.5	857	40	126	32	40	25
88	Small	616	918	49	149	32	48	50
120	Small	617	841	36	215	32	108	238
73	Small	630	880	40	227	32	44	38
227	Small	640	1580	147	233	32	44	38
173	Small	650	1420	118	8	33	41	2
144	Small	653	850.55	30	55	35	50	43
217	Small	656	865	32	1	36	44	22
18	Small	690	746	8	6	36	64	78
51	Small	700	1200	71	7	36	72	100
63	Small	700	1000	43	15	36	52	44
135	Small	700	830	19	18	36	68	89
158	Small	700	800	14	51	36	44	22
81	Small	710	915	29	94	36	40	11
199	Small	720	910	26	100	36	40	11
107	Small	720	810	13	112	36	44	22
162	Small	730	840	15	125	36	48	33
103	Small	750	810	8	127	36	40	11
108	Small	750	780	4	130	36	48	33
132	Small	752	931	24	132	36	40	11
45	Small	760	850	12	147	36	48	33
202	Small	764	850	11	196	36	44	22
228	Small	780	970	24	35	39	70	79
242	Small	792	822	4	20	40	80	100
240	Small	797	832	4	22	40	96	140
76	Small	800	1000	25	34	40	55	38
148	Small	800	900	13	58	40	60	50
79	Small	840	1140	36	63	40	55	38
75	Small	860	1080	26	85	40	72	80
216	Small	875	1220	39	110	40	48	20
237	Small	890	990	11	133	40	60	50
92	Small	900	1500	67	138	40	72	80
118	Small	910	1116	23	171	40	65	63

Project ID No	Project complexity Class	Initial contract sum (Nm)	Final cost (Nm)	Percentage cost overrun (%)	Project ID No	Estimated construction duration (Wks)	Actual construction duration (Wks)	Percentage time overrun (%)
119	Small	918	1127	23	188	40	124	210
131	Small	930	1120	20	203	40	48	20
11	Small	930	1020	10	238	40	48	20
16	Small	942	1603	70	10	41	48	17
78	Small	950	1080	14	134	42	32	-24
9	Small	965.8	1055.8	9	143	42	50	19
82	Small	973	1083	11	243	42	46	10
190	Small	980	1591	62	47	44	52	18
151	Small	980	1100	12	76	44	72	64
2	Small	981	1098	12	96	44	160	264
166	Small	1000	4000	300	140	44	75	70
95	Small	1010	2070	105	163	44	48	9
187	Small	1050	2522	140	165	44	35	-20
182	Small	1050	840	-20	218	44	112	155
215	Small	1100	1080	-2	59	45	75	67
29	Small	1100	1000	-9	70	45	60	33
89	Small	1120	5250	369	173	45	49.09	9
101	Small	1120	2100	88	209	45	66	47
114	Small	1120	1225	9	79	46	54	17
74	Small	1127	2101.97	87	113	46	78	70
20	Small	1127	1762	56	146	46	100	117
161	Small	1130	2240	98	28	47	58	23
83	Small	1150	2170	89	12	48	96	100
111	Small	1160	2180	88	16	48	75	56
112	Small	1160	2120	83	26	48	36	-25
186	Small	1170	1360	16	37	48	56	17
58	Small	1170	1320	13	42	48	52	8
198	Small	1170	1210	3	43	48	56	17
170	Small	1200	4100	242	45	48	64	33
50	Small	1200	3400	183	56	48	64	33
53	Small	1200	3400	183	71	48	42	-13
201	Small	1200	1400	17	77	48	76	58
41	Small	1200	1320	10	81	48	64	33
14	Small	1200	1310	9	107	48	64	33
31	Small	1200	1000	-17	108	48	64	33
177	Small	1240	1360	10	119	48	60	25
188	Small	1270	1350	6	136	48	36	-25
200	Small	1310	1380	5	160	48	64	33
163	Small	1320	1520	15	170	48	72	50
218	Small	1337	1541	15	177	48	192	300
172	Small	1390	1860	34	185	48	56	17
52	Small	1400	2800	100	194	48	52	8

Project ID No	Project complexity Class	Initial contract sum (Nm)	Final cost (Nm)	Percentage cost overrun (%)	Project ID No	Estimated construction duration (Wks)	Actual construction duration (Wks)	Percentage time overrun (%)
204	Small	1420	1730	22	197	48	56	17
136	Small	1490	1250	-16	198	48	66	38
124	Small	1500	3000	100	237	48	60	25
197	Small	1600	2100	31	244	48	54	13
59	Small	1600	1900	19	27	50	100	100
61	Small	1600	1900	19	239	50	63	26
191	Small	1617	1713	6	82	52	56	8
194	Small	1620	1710	6	88	52	68	31
203	Small	1663	1991	20	90	52	108	108
195	Small	1700	2080	22	91	52	76	46
49	Small	1720	1720	0	183	52	76	46
21	Small	1740	1710	-2	190	52	160	208
38	Small	1780	1990	12	191	52	160	208
55	Small	1800	3600	100	223	52	76	46
141	Small	1800	2400	33	229	52	68	31
44	Small	1850	2100	14	121	56	78	39
8	Small	1853	2010	8	156	56	72	29
127	Small	1882	2170	15	159	56	68	21
19	Small	1900	2000	5	241	56	72	29
34	Small	1980	2050	4	5	60	95	58
86	Small	1999	4005	100	30	60	80	33
85	Small	2000	7000	250	65	60	50	-17
221	Small	2000	3500	75	122	60	68	13
152	Small	2000	2180	9	144	60	44	-27
126	Small	2100	3150	50	153	60	84	40
122	Small	2110	3160	50	158	60	100	67
54	Small	2250	4460	98	166	60	64	7
100	Small	2289	3498	53	169	60	160	167
26	Small	2300	3500	52	182	60	70	17
214	Small	2400	3800	58	195	60	72	20
72	Small	2400	3180	33	213	60	72	20
106	Small	2450	3400	39	220	60	80	33
137	Small	2450	2500	2	226	62	80	29
180	Small	2500	3700	48	95	64	80	25
42	Small	2500	2800	12	118	64	76	19
109	Small	2500	2750	10	120	64	72	13
47	Small	2500	2600	4	142	64	84	31
138	Small	2550	3180	25	152	64	80	25
213	Small	2600	2800	8	154	64	76	19
157	Small	2600	2700	4	205	64	76	19
80	Small	2720	3820	40	225	64	68	6
3	Small	2758	3169	15	231	64	68	6

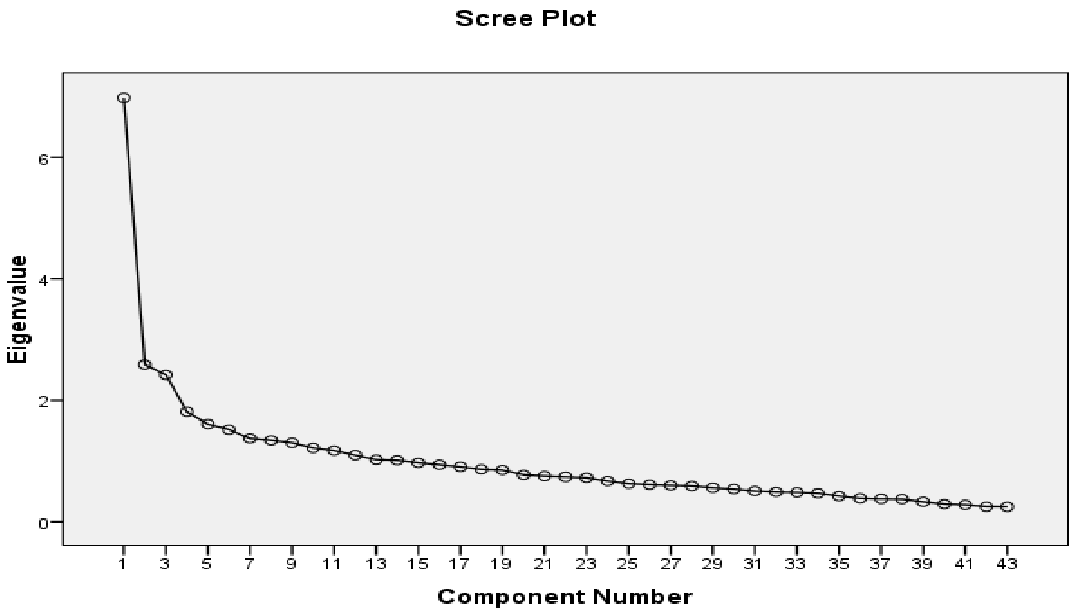
Project ID No	Project complexity Class	Initial contract sum (Nm)	Final cost (Nm)	Percentage cost overrun (%)	Project ID No	Estimated construction duration (Wks)	Actual construction duration (Wks)	Percentage time overrun (%)
171	Small	2780	4020	45	240	66	82	24
43	Small	2800	3500	25	93	68	100	47
140	Small	2800	3100	11	123	68	76	12
23	Small	2800	2500	-11	124	68	100	47
6	Small	2852	3991	40	128	68	76	12
65	Small	2890	3825	32	224	68	76	12
155	Small	3100	3450	11	19	70	100	43
5	Small	3150	4201	33	24	70	144	106
123	Small	3190	5400	69	17	72	100	39
174	Small	3300	17800	439	32	72	80	11
48	Small	3300	3800	15	36	72	96	33
71	Small	3460	4800	39	41	72	84	17
99	Small	3500	4200	20	44	72	96	33
60	Small	3500	4000	14	46	72	84	17
156	Small	3600	3900	8	49	72	72.4	1
193	Small	3700	9150.1	147	69	72	48	-33
220	Small	3900	13900	256	102	72	96	33
164	Small	3900	7900	103	105	72	104	44
224	Small	4200	5600	33	106	72	96	33
105	Small	4220	4500	7	109	72	88	22
66	Small	4320	4950	15	139	72	96	33
223	Small	4530	6650	47	150	72	96	33
192	Small	4560	6160	35	151	72	96	33
184	Small	4600	8400	83	162	72	100	39
168	Small	4800	7600	58	168	72	104	44
110	Small	4800	5200	8	174	72	120	67
33	Small	5000	15000	200	187	72	168	133
176	Small	5000	10000	100	201	72	90	25
225	Medium	5200	8100	56	212	72	98	36
181	Medium	5600	5950	6	222	72	100	39
35	Medium	5700	8900	56	3	75	110	47
175	Medium	5700	5900	4	167	76	90	18
205	Medium	5900	9000	53	176	76	168	121
165	Medium	6400	8100	27	192	76	168	121
56	Medium	7784	8181	5	206	76	164	116
222	Medium	7900	8900	13	210	76	168	121
167	Medium	8000	11000	38	116	77	98	27
160	Medium	8100	9200	14	4	80	120	50
185	Medium	8400	9600	14	68	80	100	25
226	Medium	9100	17800	96	155	80	112	40
17	Medium	9658	10275	6	172	80	120	50
219	Medium	9800	10700	9	179	80	112	40

Project ID No	Project complexity Class	Initial contract sum (Nm)	Final cost (Nm)	Percentage cost overrun (%)	Project ID No	Estimated construction duration (Wks)	Actual construction duration (Wks)	Percentage time overrun (%)
39	Medium	10000	15000	50	200	84	92	10
4	Medium	10810	15980	48	157	88	96	9
93	Medium	11000	15000	36	193	88	168	91
231	Medium	11100	12200	10	208	88	144	64
94	Medium	13500	22300	65	178	90	67.5	-25
91	Medium	13900	14100	1	175	92	152	65
37	Medium	14000	18000	29	13	96	144	50
229	Medium	14700	17500	19	25	96	104	8
90	Medium	15000	29000	93	67	96	120	25
77	Medium	15000	17000	13	141	96	120	25
28	Medium	16000	22000	38	189	96	152	58
183	Medium	17000	20000	18	199	96	112	17
169	Medium	18200	29400	62	221	96	48	-50
36	Medium	19800	20800	5	242	96	104	8
32	Medium	20000	40000	100	246	96	110	15
57	Medium	20000	40000	100	186	98	105	7
189	Complex	25000	30000	20	39	100	80	-20
146	Complex	30000	92000	207	148	100	120	20
27	Complex	30000	50000	67	245	102	150	47
96	Complex	35000	87600	150	87	108	245	127
212	Complex	38000	60200	58	33	112	160	43
208	Complex	40000	81000	103	104	112	128	14
209	Complex	47000	90000	91	202	112	160	43
24	Complex	52000	97000	87	135	120	108	-10
206	Complex	85000	260000	206	145	120	192	60
87	Complex	101000	303000	200	180	136	192	41

APPENDIX VI: Construction cost factors KMO and Bartlett's Test results

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.766
Bartlett's Test of Sphericity	Approx. Chi-Square	2718.068
	df	903
	Sig.	.000

APPENDIX VII: Construction cost factors' scree plot



APPENDIX VIII: Construction cost factors PCA or initial total variance explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	**Total**	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**
1	7.586	17.643	17.643	7.586	17.643	17.643
2	2.506	5.827	23.470	2.506	5.827	23.470
3	2.306	5.362	28.832	2.306	5.362	28.832
4	1.814	4.218	33.050	1.814	4.218	33.050
5	1.638	3.810	36.861	1.638	3.810	36.861
6	1.615	3.756	40.617	1.615	3.756	40.617
7	1.400	3.256	43.873	1.400	3.256	43.873
8	1.378	3.205	47.078	1.378	3.205	47.078
9	1.296	3.014	50.092	1.296	3.014	50.092
10	1.244	2.894	52.986	1.244	2.894	52.986
11	1.151	2.677	55.664	1.151	2.677	55.664
12	1.062	2.470	58.134	1.062	2.470	58.134
13	1.053	2.449	60.582	1.053	2.449	60.582
14	1.012	2.353	62.936	1.012	2.353	62.936
15	.972	2.260	65.196			
16	.926	2.154	67.350			
17	.908	2.111	69.461			
18	.866	2.014	71.475			
19	.821	1.908	73.383			
20	.774	1.800	75.183			
21	.746	1.735	76.919			
22	.738	1.715	78.634			

23	.687	1.598	80.232
24	.629	1.462	81.694
25	.617	1.434	83.128
26	.598	1.392	84.520
27	.581	1.350	85.870
28	.569	1.323	87.194
29	.527	1.227	88.420
30	.503	1.170	89.590
31	.474	1.103	90.693
32	.453	1.054	91.747
33	.439	1.022	92.769
34	.414	.963	93.732
35	.387	.899	94.632
36	.372	.864	95.496
37	.340	.791	96.286
38	.333	.775	97.061
39	.304	.707	97.768
40	.272	.632	98.400
41	.250	.582	98.982
42	.230	.535	99.516
43	.208	.484	100.000

Extraction Method: Principal Component Analysis.

APPENDIX IX: Construction cost factors comparison of eigenvalues from Principal Component Analysis and criterion values from Parallel Analysis

Component number	Actual eigenvalue from PCA	Criterion value from parallel analysis	Decision
1	6.978	1.9128	Accept
2	2.586	1.8101	Accept
3	2.417	1.7312	Accept
4	1.810	1.6666	Accept
5	1.605	1.6002	Accept
6	1.515	1.5483	Reject
7	1.370	1.4963	Reject
8	1.340	1.4523	Reject
9	1.298	1.4057	Reject
10	1.214	1.3611	Reject

APPENDIX X: Construction cost factors' parallel analysis total variance explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	6.978	16.227	16.227	6.978	16.227	16.227	3.952
2	2.586	6.014	22.241	2.586	6.014	22.241	2.339
3	2.417	5.622	27.863	2.417	5.622	27.863	3.853
4	1.810	4.209	32.072	1.810	4.209	32.072	4.743
5	1.605	3.732	35.804	1.605	3.732	35.804	3.954
6	1.515	3.524	39.329				
7	1.370	3.186	42.515				
8	1.340	3.115	45.630				
9	1.298	3.020	48.650				
10	1.214	2.823	51.472				
11	1.171	2.723	54.195				
12	1.094	2.544	56.739				
13	1.021	2.374	59.113				
14	1.011	2.351	61.465				
15	.969	2.254	63.719				
16	.938	2.181	65.900				
17	.902	2.098	67.998				
18	.860	2.001	69.999				
19	.849	1.974	71.973				
20	.771	1.793	73.766				
21	.751	1.746	75.513				
22	.738	1.717	77.230				
23	.723	1.681	78.910				
24	.669	1.557	80.467				
25	.626	1.457	81.924				
26	.609	1.416	83.339				
27	.598	1.390	84.730				
28	.588	1.367	86.097				
29	.558	1.298	87.395				
30	.537	1.248	88.644				
31	.505	1.175	89.819				
32	.490	1.139	90.958				
33	.484	1.125	92.082				
34	.467	1.087	93.169				
35	.421	.978	94.147				
36	.384	.893	95.040				
37	.376	.875	95.915				
38	.372	.864	96.779				

39	.326	.758	97.537
40	.290	.674	98.210
41	.278	.646	98.856
42	.247	.574	99.430
43	.245	.570	100.000

Extraction Method: Principal Component Analysis.
a. When components are correlated, sums of squared loadings cannot be added to obtain a total variance.

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.

APPENDIX XI: Construction cost factors component correlation matrix

Component	**1**	**2**	**3**	**4**	**5**
1	1.000	.080	.127	.262	.282
2	.080	1.000	-.014	-.068	.047
3	.127	-.014	1.000	.227	.168
4	.262	-.068	.227	1.000	.264
5	.282	.047	.168	.264	1.000

APPENDIX XII: Construction cost factors pattern and structure matrix for Principal Component Analysis (PCA) with Oblimin rotation of five factor solution

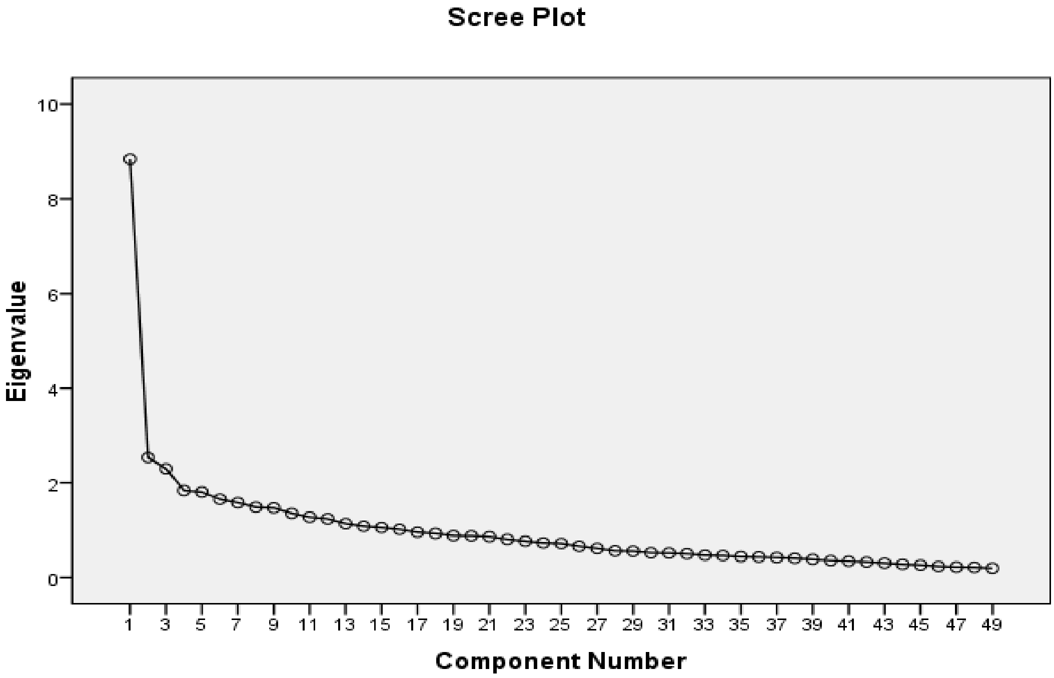
Factor	Pattern coefficients					Structure coefficients					Communalities
	CFC 1	CFC 2	CFC 3	CFC 4	CFC 5	CFC 1	CFC 2	CFC 3	CFC 4	CFC 5	
Payment delays to sub-contractor and supplier	.667					.647					.445
Payment delays to main contractor	.646					.657					.454
Contract information delay	.555					.581					.351
Inadequate prime cost and provisional sum	.527					.574					.351
Unstable and high interest rate	.423					.495	.333			.336	.373
Variations to works	.403					.418					.239
External parties' influence	.322					.407				.302	.240
Changes in material specifications	.319					.414				.362	.246
Fluctuation/Inflation of price		.674					.675				.531
Inaccurate cost estimate		.553					.537	.313			.413
Contractor's poor cost/financial management		.464					.464			.412	.403
Unstable foreign exchange		.389					.408				.259
Design changes			.750					.706			.556
Changes in specifications		.325	.651				.323	.599			.506
Design errors			.567					.570			.355
Cash flow problems			.507					.555		.440	.346
Contractor's inability to manage risks and uncertainties			.494					.562			.474
Poor labour productivity			.489					.554	.335		.371

Lack of communication between parties		-.383	.451				-.369	.508			.462
Non-performance of subcontractors		-.304	.356				-.302	.429	.335		.371
Project complexity			.335					.411	.309		.298
Conflict between contractual parties	.315		.323			.372		.392	.306		.302
Lack of co-ordination of project parties				.677					.653		.454
Contractors' improper contract knowledge				.646					.654		.446
Industrial unrest/strikes				.645					.649		.430
Unforeseen site/soil conditions				.636					.620		.427
Delays in the delivery of imported materials				.564					.544	.301	.380
Inadequate project monitoring				.537					.577		.419
Fuel shortage				.505					.526		.346
Fraud/corrupt practices				.452		.327		.323	.506		.393
Rework due to mistakes				.352					.447	.398	.272
Shortage of labour				.347	.328				.450		.376
Contract manager's inexperience				.306					.381		.196
Non-adherence to contract conditions					.561					.577	.366
Poor cost control system					.485					.538	.409
Discrepancy/deficiency in contract documents					.480					.499	.291
Economic insecurity					.455		.305			.494	.353
Weak regulations and control					.434	.310				.483	.282
Low quality materials					.429	.335				.466	.307
Shortage of equipment					.424					.449	.225
Lack of relevant information and details					.407			.309		.433	.284
Delay in equipment supply					.321	.356				.398	.240
Government's changes in policy and fiscal measures										.319	.152

APPENDIX XIII: Construction time factors' KMO and Bartlett's Test results

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.785
Bartlett's Test of Sphericity	Approx. Chi-Square	3709.886
	df	1176
	Sig.	.000

APPENDIX XIV: Construction time factors scree plot



APPENDIX XV: Construction time factors' initial or PCA Eigenvalues/Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	7.900	16.122	16.122	7.900	16.122	16.122
2	2.544	5.192	21.314	2.544	5.192	21.314
3	2.268	4.628	25.942	2.268	4.628	25.942
4	1.933	3.945	29.886	1.933	3.945	29.886
5	1.799	3.672	33.558	1.799	3.672	33.558
6	1.737	3.546	37.104	1.737	3.546	37.104
7	1.668	3.403	40.507	1.668	3.403	40.507
8	1.613	3.292	43.799	1.613	3.292	43.799
9	1.544	3.151	46.951	1.544	3.151	46.951
10	1.455	2.969	49.919	1.455	2.969	49.919
11	1.401	2.858	52.778	1.401	2.858	52.778

12	1.293	2.640	55.417	1.293	2.640	55.417
13	1.233	2.517	57.934	1.233	2.517	57.934
14	1.206	2.462	60.396	1.206	2.462	60.396
15	1.091	2.227	62.623	1.091	2.227	62.623
16	1.076	2.195	64.818	1.076	2.195	64.818
17	1.042	2.127	66.946	1.042	2.127	66.946
18	1.005	2.052	68.997	1.005	2.052	68.997
19	.952	1.944	70.941			
20	.925	1.887	72.828			
21	.842	1.718	74.546			
22	.826	1.685	76.231			
23	.786	1.604	77.835			
24	.766	1.563	79.398			
25	.708	1.446	80.844			
26	.647	1.321	82.165			
27	.611	1.247	83.412			
28	.594	1.213	84.625			
29	.576	1.176	85.801			
30	.554	1.131	86.932			
31	.524	1.070	88.002			
32	.497	1.015	89.016			
33	.482	.983	89.999			
34	.447	.913	90.912			
35	.432	.881	91.793			
36	.416	.848	92.641			
37	.402	.820	93.461			
38	.382	.780	94.241			
39	.372	.759	95.000			
40	.321	.655	95.655			
41	.302	.616	96.270			
42	.299	.610	96.880			
43	.279	.569	97.449			
44	.253	.517	97.966			
45	.247	.504	98.470			
46	.208	.424	98.894			
47	.190	.387	99.281			

48	.185	.377	99.658
49	.167	.342	100.000

Extraction Method: Principal Component Analysis.

APPENDIX XVI: Construction time factors' comparison of eigenvalues from Principal Component Analysis and criterion values from Parallel Analysis

Component number	Actual eigenvalue from PCA	Criterion value from parallel analysis	Decision
1	8.837	1.9868	Accept
2	2.536	1.8897	Accept
3	2.297	1.8039	Accept
4	1.841	1.7426	Accept
5	1.808	1.6847	Accept
6	1.658	1.6314	Accept
7	1.584	1.5751	Accept
8	1.489	1.5260	Reject
9	1.474	1.4829	Reject
10	1.356	1.4412	Reject

APPENDIX XVII: Construction time factors' parallel analysis Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	8.837	18.034	18.034	8.837	18.034	18.034
2	2.536	5.176	23.210	2.536	5.176	23.210
3	2.297	4.688	27.898	2.297	4.688	27.898
4	1.841	3.758	31.656	1.841	3.758	31.656
5	1.808	3.691	35.347	1.808	3.691	35.347
6	1.658	3.383	38.730	1.658	3.383	38.730
7	1.584	3.232	41.963	1.584	3.232	41.963
8	1.489	3.038	45.001			
9	1.474	3.007	48.008			
10	1.356	2.766	50.775			
11	1.276	2.604	53.379			
12	1.240	2.530	55.909			
13	1.140	2.326	58.234			
14	1.084	2.213	60.447			
15	1.056	2.156	62.603			
16	1.019	2.079	64.682			
17	.958	1.956	66.638			
18	.933	1.905	68.543			

19	.887	1.811	70.353
20	.882	1.801	72.154
21	.864	1.763	73.917
22	.807	1.648	75.565
23	.769	1.570	77.136
24	.734	1.497	78.633
25	.720	1.470	80.103
26	.663	1.352	81.455
27	.618	1.261	82.716
28	.565	1.154	83.870
29	.559	1.142	85.012
30	.525	1.071	86.082
31	.520	1.062	87.144
32	.504	1.028	88.172
33	.475	.970	89.142
34	.465	.950	90.092
35	.444	.905	90.997
36	.436	.890	91.887
37	.424	.866	92.753
38	.409	.835	93.588
39	.387	.790	94.378
40	.360	.734	95.112
41	.348	.709	95.821
42	.328	.670	96.491
43	.306	.624	97.115
44	.279	.570	97.685
45	.265	.541	98.226
46	.235	.480	98.706
47	.221	.452	99.158
48	.216	.440	99.598
49	.197	.402	100.000

Extraction Method: Principal Component Analysis.

APPENDIX XVIII: Construction time factors component correlation matrix

Component	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1	1.000	.184	.157	.187	.218	-.237	.112
2	.184	1.000	.145	.171	.234	-.142	.029

3	.157	.145	1.000	.144	.145	-.145	.081
4	.187	.171	.144	1.000	.306	-.174	.166
5	.218	.234	.145	.306	1.000	-.174	.105
6	-.237	-.142	-.145	-.174	-.174	1.000	-.076
7	.112	.029	.081	.166	.105	-.076	1.000

Extraction Method: Principal Component Analysis.

Rotation Method: Oblimin with Kaiser Normalization.

APPENDIX XIX: Time factors pattern and structure matrix for Principal Component Analysis (PCA) with Oblimin rotation of seven factor solutions

Factors	Pattern coefficients							Structure coefficients							Communalities
	TFC1	TFC2	TFC3	TFC4	TFC5	TFC6	TFC7	TFC1	TFC2	TFC3	TFC4	TFC5	TFC6	TFC7	
Industrial unrest/strikes	**.761**							.743							.582
Delay in the delivery of imported materials	**.661**							.694							.522
Fuel shortage	**.636**							.651							.468
Shortage of labour	**.414**						.355	.512					-.316	.425	.445
Unforeseen site/soil conditions	.375							.472						.368	.372
Contractor's inability to manage risks and uncertainty	.319							.412					-.330		.260
Programme/schedule delay	.318							.384	.369			.302			.379
Civil commotion/community issues		**.774**							.754						.607
Lack of relevant tools and equipment		**.662**							.669						.541
Political instability		**.638**							.652						.479
Insecurity/insurgency		**.628**							.645						.439
Force majeure		**.613**							.606						.538
Obsolete/unsuitable construction equipment		**.483**							.517		.397				.451
Unclear and inadequate instructions to operators		.375		.305					.449		.406				.346
Inclement weather									.338						.267
Bureaucracy in client's organization			**.730**							.722					.534
Client's slowness in decision making			**.602**							.620					.453

Incomplete technical documentations	.323		**.567**					.403		.609					.555
Site accident			**.489**			-.308		.344		.537			-.391		.506
Client's undue interference			.397							.454	.380	.318			.350
Delay in building permit approval				**.653**							.640				.444
Inadequate planning and scheduling				**.628**											.450
Natural disaster such as flood				**.596**							.575				.393
Contractor's inexperience				**.558**							.597				.384
Poor site management and supervision				**.501**							.551				.342
Delay in inspection and testing of completed work				**.466**							.505				.316
Contractors' improper contract knowledge				**.447**							.517		-.327		.399
Delay in drawing preparations and approval				.384						.325	.459			.308	.364
Variation to works					**.685**							.617			.480
Design changes					**.577**							.579			.367
Changes in specifications					**.472**			.324				.513			.332
Poor construction programme management					**.462**					.348		.513			.346
Design errors					**.459**		.346	.314				.504		.404	.455
Payment delays to main contractor					**.442**	-.406	-.314					.499	-.463		.507
Contract manager's inexperience					**.405**			.353				.482			.338

Contract information delay				.397	-.325					.323	.485	-.400		.375
Payment delays to sub-contractor supplier				.385		-.365					.428			.383
Inadequate prime cost and provisional sum				.378							.461	-.321		.290
Poor project management	.302			.334				.404		.420	.466			.429
Inadequate project monitoring										.380	.387	-.300		.314
Lack of co-ordination of project parties							.373			.312	.387		.315	.328
Inadequate planning and scheduling										.638	.344			.204
Cash flow problems					**-.647**							-.675		.490
Poor labour productivity					**-.601**		.343					-.652		.481
Project complexity					**-.597**							-.625		.421
Lack of communication between parties					-.540							-.586		.406
Reworks due to mistakes						.584						-.319	.614	.481
Conflict between contractual parties						.541	.357					-.303	.586	.501
Non-performance of subcontractors						.494			.306				.545	.459

APPENDIX XX: Cost impact models training dataset

S/No	BC 23	BC 21	BC 13	BC 18	BC 43	BC 9	BC 19	BC 29	BC 20	C. Imp (t_j)	Partition
1	2	1	2	2	5	1	3	1	1	0.40	Training
2	2	4	4	3	4	3	2	3	4	0.12	Training
4	2	4	3	3	3	3	4	3	2	0.48	Training
5	5	3	3	2	4	4	4	1	1	0.33	Training
6	0	0	5	2	0	2	0	2	0	0.40	Training
7	4	4	3	3	3	4	3	4	4	0.28	Training
8	4	2	4	3	1	2	2	3	3	0.09	Training
9	0	3	5	5	1	2	5	3	3	0.09	Training
10	2	3	3	2	2	4	3	2	3	0.47	Training
11	3	5	2	3	4	4	3	3	4	0.10	Training
12	4	4	4	1	1	3	3	1	3	0.75	Training
13	0	0	4	3	0	0	0	0	0	0.09	Training
14	3	5	4	5	5	5	4	5	3	0.10	Training
15	4	1	0	0	0	1	0	0	1	0.70	Training
16	0	3	0	5	0	0	1	4	1	0.06	Training
17	4	2	4	4	5	3	4	4	3	0.08	Training
18	2	5	3	4	1	3	1	0	0	0.05	Training
19	2	3	2	3	3	1	4	4	3	0.56	Training
20	2	0	4	0	0	4	0	3	0	-0.02	Training
21	2	5	3	4	1	3	2	4	2	0.03	Training
22	1	4	2	2	0	4	2	0	3	-0.11	Training
23	5	1	5	2	1	4	1	0	2	0.87	Training
24	3	3	4	1	1	3	2	2	1	0.42	Training
25	5	5	5	5	4	1	3	4	4	0.52	Training
26	4	3	5	4	5	4	2	5	3	0.67	Training
27	3	2	2	3	2	2	4	3	3	0.38	Training
28	3	0	5	4	5	4	3	3	5	-0.09	Training
29	4	3	4	3	3	5	2	3	5	0.67	Training
30	4	3	4	2	2	4	2	2	5	-0.17	Training
31	2	3	3	0	0	1	3	1	1	0.04	Training
32	5	5	3	4	5	3	5	3	4	0.56	Training
33	5	5	4	5	2	3	5	3	5	0.05	Training
34	1	2	4	3	5	1	5	0	3	0.29	Training
35	4	2	3	3	1	1	2	1	2	0.12	Training
36	1	5	1	5	3	1	3	3	3	0.50	Training
37	2	2	4	1	1	4	3	0	1	0.60	Training
38	3	5	2	3	0	3	4	4	4	0.10	Training
39	0	2	4	3	2	3	2	0	2	0.12	Training
40	2	2	2	2	4	2	2	0	2	0.25	Training
41	1	0	1	1	0	0	2	0	0	0.14	Training
42	0	0	1	0	4	1	0	4	0	0.12	Training
43	3	5	3	2	3	1	2	3	3	0.07	Training
44	2	3	2	5	3	3	5	2	4	0.04	Training
45	1	3	2	1	5	2	2	2	3	0.15	Training

46	1	3	3	4	3	3	5	3	4	0.00	Training
47	4	4	2	0	2	3	2	3	3	0.71	Training
48	4	1	1	3	3	1	1	1	3	0.05	Training
49	4	4	5	3	5	3	2	2	3	0.13	Training
50	3	3	1	5	1	0	0	1	2	0.19	Training
51	5	1	2	1	0	4	2	2	4	0.14	Training
52	4	4	1	4	0	4	3	2	3	0.19	Training
53	0	0	2	1	0	3	2	0	1	0.43	Training
54	2	1	4	3	3	4	3	5	2	0.40	Training
55	3	3	3	2	2	4	4	3	3	0.32	Training
56	3	0	4	4	4	5	2	4	1	0.15	Training
57	1	5	5	4	1	5	2	3	2	0.14	Training
58	5	5	5	5	4	4	5	2	5	0.26	Training
59	2	3	4	3	4	2	3	3	4	0.57	Training
60	2	4	1	3	4	3	2	2	3	-0.02	Training
61	0	1	1	0	3	3	1	1	1	0.39	Training
62	3	4	4	3	0	4	4	3	4	0.33	Training
63	4	3	2	2	5	1	3	0	1	0.40	Training
64	4	2	2	3	3	4	4	3	0	0.87	Training
65	3	4	4	4	2	3	2	2	3	0.26	Training
66	5	2	2	3	1	3	1	0	4	0.25	Training
67	2	4	2	2	4	1	4	5	3	0.13	Training
68	4	5	4	2	3	5	3	2	1	0.14	Training
69	5	5	2	4	5	1	4	1	4	0.36	Training
70	0	2	4	4	0	1	2	1	5	0.40	Training
71	4	2	0	3	2	2	2	5	1	0.29	Training
72	3	3	2	3	3	2	3	2	3	0.11	Training
73	3	2	0	3	4	3	1	4	0	0.89	Training
74	4	2	2	1	1	2	2	1	3	0.75	Training
75	4	2	4	3	5	2	4	3	3	0.49	Training
76	0	2	4	5	5	2	3	3	0	0.93	Training
77	0	0	3	3	0	2	1	0	0	0.01	Training
78	3	2	2	5	0	4	4	0	3	0.67	Training
79	2	3	0	1	4	2	3	2	5	0.36	Training
80	5	3	5	2	4	2	1	3	5	0.65	Training
81	4	1	2	0	5	3	2	2	3	0.37	Training
82	1	2	0	2	3	2	3	3	0	0.20	Training
83	3	0	5	3	5	3	5	4	2	0.53	Training
84	3	3	3	3	4	5	0	4	5	0.88	Training
85	3	2	3	2	3	1	3	5	4	0.49	Training
86	1	2	2	3	2	1	2	3	1	0.08	Training
87	3	2	2	2	5	1	3	1	4	0.16	Training
88	1	1	1	4	1	3	3	3	2	0.07	Training
89	2	2	3	3	3	2	4	3	3	0.39	Training
90	2	0	3	4	3	4	5	3	1	0.13	Training
91	3	1	3	2	0	5	1	2	0	0.04	Training

92	5	2	3	2	1	3	4	5	1	0.10	Training
93	3	5	1	2	5	5	4	3	5	0.08	Training
94	5	5	4	3	2	5	1	2	2	0.88	Training
95	2	4	2	5	3	0	2	3	0	0.83	Training
96	4	2	5	4	2	3	5	0	0	0.35	Training
97	3	2	2	3	0	1	5	1	1	0.09	Training
98	5	3	3	4	5	3	1	3	3	0.53	Training
99	5	3	3	3	0	3	1	3	2	0.33	Training
100	5	5	3	2	2	3	2	3	0	0.23	Training
101	1	5	0	1	5	0	2	2	3	0.23	Training
102	3	3	1	0	4	3	5	5	3	0.36	Training
103	5	1	5	4	2	5	3	5	5	0.24	Training
104	3	3	5	1	2	1	4	3	2	0.50	Training
105	5	0	4	3	4	5	4	0	1	0.69	Training
106	2	4	3	3	5	3	2	2	3	0.21	Training
107	5	4	2	3	3	2	2	3	3	0.50	Training
108	1	1	1	1	0	5	5	2	3	0.15	Training
109	4	1	2	1	3	4	3	2	3	0.27	Training
110	5	2	4	0	5	5	4	5	3	0.72	Training
111	4	3	3	0	5	2	2	3	3	0.31	Training
112	4	1	3	2	2	3	3	3	4	0.20	Training
113	5	4	2	1	5	2	3	5	4	0.24	Training
114	5	1	2	3	5	4	4	1	3	0.50	Training
115	3	5	5	2	5	5	3	4	4	0.29	Training
116	0	5	0	2	3	4	1	5	1	0.19	Training
117	2	2	3	2	0	3	0	2	2	-0.16	Training
118	4	4	5	3	4	3	2	5	3	0.02	Training
119	4	4	4	3	4	4	4	4	4	0.25	Training
120	0	2	3	3	0	3	0	0	0	0.47	Training
121	4	4	3	3	4	3	4	4	3	0.11	Training
122	1	4	3	4	3	3	4	3	3	0.33	Training
123	4	4	2	5	2	3	5	3	4	0.50	Training
124	4	4	4	4	0	2	2	4	0	0.30	Training
125	0	4	2	2	0	2	2	0	1	0.37	Training
126	4	5	4	3	4	3	1	4	3	0.13	Training
127	5	3	5	1	0	3	0	4	5	0.16	Training
128	3	3	2	1	1	3	2	5	1	0.04	Training
129	5	3	0	3	1	4	5	5	2	0.12	Training
130	3	3	5	2	1	5	1	2	2	0.09	Training
131	5	1	0	5	0	1	1	0	5	0.24	Training
132	5	4	1	2	2	1	4	3	4	0.10	Training
133	5	5	4	2	3	3	5	4	1	0.11	Training
134	1	0	5	3	0	1	1	1	3	0.08	Training
135	1	4	1	1	1	5	4	3	5	0.04	Training
136	3	2	2	2	1	1	3	3	0	0.14	Training
137	3	1	2	0	4	3	2	3	3	0.14	Training

138	2	4	3	4	4	2	4	2	4	0.98	Training
139	5	4	3	2	0	0	3	3	1	0.15	Training
140	5	5	3	5	5	3	5	0	5	0.15	Training
141	3	3	5	2	2	5	2	2	3	0.27	Training
142	5	5	0	0	4	2	5	5	5	0.38	Training
143	4	4	2	4	3	1	4	2	4	0.58	Training
144	4	5	3	0	5	2	2	1	3	0.62	Training
145	5	1	3	2	2	1	0	5	4	0.45	Training
146	3	0	3	5	3	2	0	2	1	0.34	Training
147	3	5	1	4	5	0	2	5	1	0.04	Training
148	4	2	3	4	5	4	3	3	3	0.10	Training
149	0	3	4	3	5	1	2	3	3	0.80	Training
150	1	4	3	3	1	2	2	2	2	-0.01	Training
151	1	5	5	4	5	3	3	3	2	0.48	Training
152	0	0	0	5	0	0	5	0	5	0.06	Training
153	0	0	0	0	0	0	1	0	0	-0.20	Training
154	3	3	2	4	4	1	1	2	2	0.18	Training
155	3	4	4	2	4	5	3	3	4	0.83	Training
156	1	1	1	0	1	0	2	0	5	0.14	Training
157	5	5	1	4	5	3	5	5	5	0.16	Training
158	2	3	5	2	5	3	3	2	2	0.06	Training
159	2	1	3	4	3	3	2	3	2	0.20	Training
160	3	5	4	5	5	2	3	4	4	0.62	Training
161	5	2	1	0	4	1	1	4	3	0.06	Training
162	1	2	4	0	3	1	3	2	1	0.35	Training
163	4	1	2	5	0	1	2	5	4	0.06	Training
164	5	5	4	2	0	3	4	2	5	0.22	Training
165	5	5	3	3	0	1	5	3	5	0.19	Training
166	1	2	4	2	2	5	2	5	2	0.31	Training
167	5	4	1	1	5	4	1	5	2	0.03	Training
168	3	1	0	0	3	2	0	4	3	0.26	Training

APPENDIX XXI: Duration impact model training dataset

.S/No	BT. 76	BT. 79	BT. 71	BT. 69	BT. 49	BT. 92	BT. 55	BT. 82	BT. 75	BT. 67	Actual Impact	Partition
1	3	2	2	2	2	1	3	3	4	1	0.22	Training
2	1	3	2	1	1	2	3	1	1	1	0.47	Training
3	3	3	3	2	2	3	2	2	3	2	0.50	Training
4	4	4	1	1	1	5	2	2	2	2	0.58	Training
5	0	0	0	0	0	0	2	0	0	1	0.78	Training
6	2	2	4	3	3	2	1	2	2	3	0.24	Training
7	3	3	3	3	3	1	0	1	3	3	0.17	Training
8	2	2	1	1	1	3	1	2	2	2	0.17	Training
9	1	1	1	1	1	1	4	1	2	3	0.50	Training
10	3	5	4	4	4	5	3	5	3	4	0.44	Training
11	1	0	0	0	0	0	3	1	1	0	0.56	Training
12	2	3	2	1	1	0	0	0	5	5	0.39	Training
13	4	4	5	5	5	4	5	4	4	4	0.89	Training
14	1	2	5	2	2	1	1	0	4	2	0.43	Training
15	0	3	0	1	1	3	0	1	0	1	0.33	Training
16	0	3	1	1	1	3	0	1	0	0	0.67	Training
17	2	3	1	2	2	1	0	2	1	2	0.08	Training
18	5	5	5	3	3	5	0	3	4	2	-0.25	Training
19	4	2	3	5	5	2	3	2	3	3	0.23	Training
20	3	3	3	1	1	0	1	3	1	5	0.33	Training
21	0	3	5	3	3	1	0	4	1	1	0.50	Training
22	2	4	3	1	1	4	4	3	3	4	0.11	Training
23	3	5	3	2	2	5	2	1	4	3	0.43	Training
24	3	3	3	0	0	3	0	1	5	2	0.38	Training
25	3	1	3	2	2	3	5	2	3	3	0.80	Training
26	4	1	1	0	0	1	2	1	5	1	0.33	Training
27	1	5	3	3	3	3	3	3	2	3	0.17	Training
28	2	1	3	1	1	3	5	2	3	3	0.50	Training
29	5	2	1	5	5	4	3	1	0	0	-0.20	Training
30	4	5	3	4	4	0	4	0	4	5	0.17	Training

31	1	1	4	5	5	2	5	2	2	5	0.08	Training
32	5	5	5	5	5	5	3	5	5	5	0.17	Training
33	2	2	0	1	1	5	1	3	2	0	0.33	Training
34	3	2	2	4	4	0	0	5	2	3	0.33	Training
35	4	3	3	4	4	3	0	2	3	2	0.17	Training
36	2	3	4	2	2	3	1	3	1	3	0.18	Training
37	3	2	4	2	2	1	1	3	3	5	0.25	Training
38	4	3	1	3	3	2	2	2	2	3	0.01	Training
39	1	2	2	2	2	1	5	4	0	0	0.22	Training
40	2	5	3	5	5	3	3	2	1	3	0.67	Training
41	3	4	1	0	0	4	4	0	2	3	0.65	Training
42	3	1	0	4	4	2	1	3	2	2	0.25	Training
43	1	0	0	3	3	0	4	3	1	3	0.43	Training
44	3	1	3	3	3	5	1	2	2	3	0.33	Training
45	0	3	1	2	2	3	4	1	2	1	0.50	Training
46	2	1	3	4	4	3	3	5	5	2	0.67	Training
47	3	1	4	2	2	0	1	1	3	4	0.50	Training
48	1	2	3	3	3	1	2	1	1	3	0.38	Training
49	3	3	4	3	3	4	3	2	4	3	0.10	Training
50	3	2	3	3	3	2	3	1	5	3	-0.17	Training
51	3	2	3	0	0	0	1	0	1	2	0.13	Training
52	4	3	1	0	0	1	0	2	0	4	0.25	Training
53	5	3	1	1	1	2	5	3	3	3	0.25	Training
54	5	1	4	3	3	3	2	5	3	5	-0.33	Training
55	3	4	3	2	2	5	4	4	3	2	0.33	Training
56	3	1	3	5	5	0	0	4	2	5	-0.13	Training
57	2	2	3	2	2	5	4	3	3	1	0.33	Training
58	3	5	4	5	5	4	4	4	1	2	0.25	Training
59	3	3	2	3	3	1	5	4	3	2	0.14	Training
60	1	5	3	3	3	3	3	5	1	3	0.64	Training
61	3	4	2	5	5	4	1	1	4	4	0.58	Training
62	2	2	1	5	5	0	2	3	0	3	0.17	Training
63	5	5	0	5	5	4	1	2	1	1	0.33	Training
64	4	1	4	5	5	3	4	4	3	4	0.08	Training

65	4	3	3	2	2	3	4	3	2	1	0.20	Training
66	3	4	2	2	2	5	3	3	5	3	0.83	Training
67	2	4	2	5	5	5	4	4	4	1	0.80	Training
68	0	0	1	0	0	0	1	0	1	2	0.31	Training
69	5	5	5	5	5	4	3	3	5	5	0.46	Training
70	4	1	1	3	3	4	5	4	3	4	0.47	Training
71	2	0	2	4	4	2	3	2	3	3	0.11	Training
72	1	4	3	4	4	1	3	0	3	0	0.25	Training
73	3	4	3	5	5	1	5	4	5	3	0.69	Training
74	4	5	5	4	4	3	0	5	4	3	0.11	Training
75	3	2	5	3	3	2	4	1	2	5	0.33	Training
76	2	3	4	2	2	2	2	2	1	0	0.33	Training
77	0	3	3	1	1	0	3	2	3	3	0.38	Training
78	3	2	2	4	4	3	3	3	4	2	0.14	Training
79	3	2	1	2	2	3	0	3	4	2	0.44	Training
80	2	1	3	1	1	3	3	2	4	3	0.33	Training
81	3	2	3	2	2	2	3	5	2	4	0.33	Training
82	2	4	2	4	4	1	0	1	3	2	0.33	Training
83	3	2	0	3	3	3	1	5	5	2	0.22	Training
84	5	2	3	2	2	5	3	0	5	3	0.20	Training
85	3	2	3	2	2	5	0	2	2	2	0.29	Training
86	2	5	5	3	3	3	1	2	4	3	0.22	Training
87	3	3	2	3	3	2	3	2	2	5	0.70	Training
88	2	2	1	0	0	4	0	2	2	3	0.27	Training
89	5	5	2	2	2	5	5	3	3	4	0.67	Training
90	5	4	0	2	2	5	1	3	5	3	0.19	Training
91	2	5	0	4	4	5	1	3	3	1	0.25	Training
92	2	5	1	5	5	5	0	2	3	5	0.13	Training
93	1	1	1	2	2	2	1	3	3	3	0.39	Training
94	5	1	3	1	1	0	2	4	3	4	0.13	Training
95	3	3	5	1	1	5	3	5	1	4	0.12	Training
96	3	2	3	2	2	1	4	3	1	2	0.47	Training
97	4	3	5	5	5	5	5	3	3	3	0.33	Training
98	4	3	3	4	4	5	4	4	1	1	0.25	Training

99	5	2	3	1	1	4	1	3	2	1	0.11	Training
100	2	2	3	4	4	4	4	2	4	1	0.12	Training
101	5	0	1	4	4	3	5	5	0	0	0.29	Training
102	3	3	5	1	1	5	5	2	2	1	0.33	Training
103	2	3	3	1	1	2	5	1	4	4	0.67	Training
104	4	5	5	2	2	5	5	2	2	2	0.11	Training
105	5	3	4	1	1	4	5	3	5	2	0.50	Training
106	1	5	4	3	3	1	2	3	1	4	-0.24	Training
107	0	5	5	1	1	0	2	1	0	1	-0.10	Training
108	2	1	2	1	1	1	1	1	2	2	-0.25	Training
109	4	5	4	4	4	4	5	3	3	3	0.00	Training
110	3	4	4	3	3	3	4	4	2	4	0.80	Training
111	1	3	3	3	3	1	2	2	2	1	0.33	Training
112	4	4	4	4	4	4	3	3	4	4	0.71	Training
113	2	3	4	4	4	1	0	2	4	4	0.25	Training
114	3	2	4	4	4	4	5	1	4	4	0.31	Training
115	1	5	5	4	4	5	1	4	1	1	0.19	Training
116	3	1	4	2	2	0	0	1	3	4	-0.27	Training
117	1	2	3	3	3	1	1	1	1	3	0.60	Training
118	3	2	3	3	3	2	4	1	5	3	0.33	Training
119	3	2	3	0	0	0	4	0	1	2	0.20	Training
120	5	1	2	3	3	5	4	3	3	3	0.50	Training
121	5	5	2	1	1	2	5	1	5	3	0.33	Training
122	5	1	0	1	1	2	0	0	3	0	0.33	Training
123	1	5	1	0	0	3	4	3	3	2	0.25	Training
124	5	3	1	3	3	0	4	2	2	4	0.40	Training
125	3	0	0	2	2	3	0	4	4	5	0.19	Training
126	4	3	0	0	0	3	2	0	0	1	0.40	Training
127	3	2	5	5	5	3	4	3	5	3	0.29	Training
128	5	1	2	5	5	2	0	2	3	4	0.09	Training
129	4	3	1	0	0	1	2	2	0	4	0.67	Training
130	5	3	1	1	1	2	3	3	3	3	0.21	Training
131	5	1	4	3	3	3	3	5	3	5	0.33	Training
132	3	4	3	2	2	5	2	4	3	2	0.50	Training

133	2	2	3	2	2	5	1	3	3	1	0.39	Training
134	5	5	2	2	2	3	4	5	2	2	0.09	Training
135	3	3	2	3	3	1	3	4	3	2	-0.21	Training
136	1	5	3	3	3	3	4	5	1	3	0.07	Training
137	3	4	2	5	5	4	4	1	4	4	0.18	Training
138	3	3	1	1	1	4	0	3	1	1	0.44	Training
139	2	1	0	5	5	4	1	2	0	1	0.50	Training
140	5	5	0	5	5	4	3	2	1	1	0.63	Training
141	4	1	4	5	5	3	3	4	3	4	0.50	Training
142	4	3	3	2	2	3	5	3	2	1	0.09	Training
143	3	4	2	2	2	5	5	3	5	3	0.67	Training
144	2	4	2	5	5	5	5	4	4	1	0.65	Training
145	0	0	1	0	0	0	3	0	1	2	-0.25	Training
146	2	4	1	3	3	0	0	1	2	2	0.40	Training
147	4	4	5	4	4	3	2	5	5	4	0.41	Training
148	0	0	0	0	0	0	0	0	2	1	0.17	Training
149	4	1	1	3	3	4	0	4	3	4	0.46	Training
150	2	0	2	4	4	2	2	2	3	3	0.25	Training
151	1	4	3	4	4	1	1	0	3	0	0.17	Training
152	3	3	3	2	2	0	2	5	2	5	0.07	Training
153	1	3	4	2	2	2	3	2	2	1	0.58	Training
154	0	2	3	3	3	1	0	2	3	3	0.91	Training
155	5	0	5	1	1	0	0	4	3	0	0.08	Training
156	3	4	5	1	1	5	5	5	4	3	0.20	Training
157	3	4	5	5	5	5	5	2	4	2	0.22	Training
158	3	0	2	0	0	5	5	3	4	2	0.17	Training
159	3	3	2	1	1	4	2	4	3	1	0.38	Training

APPENDIX XXII: New dataset for cost impact models validations

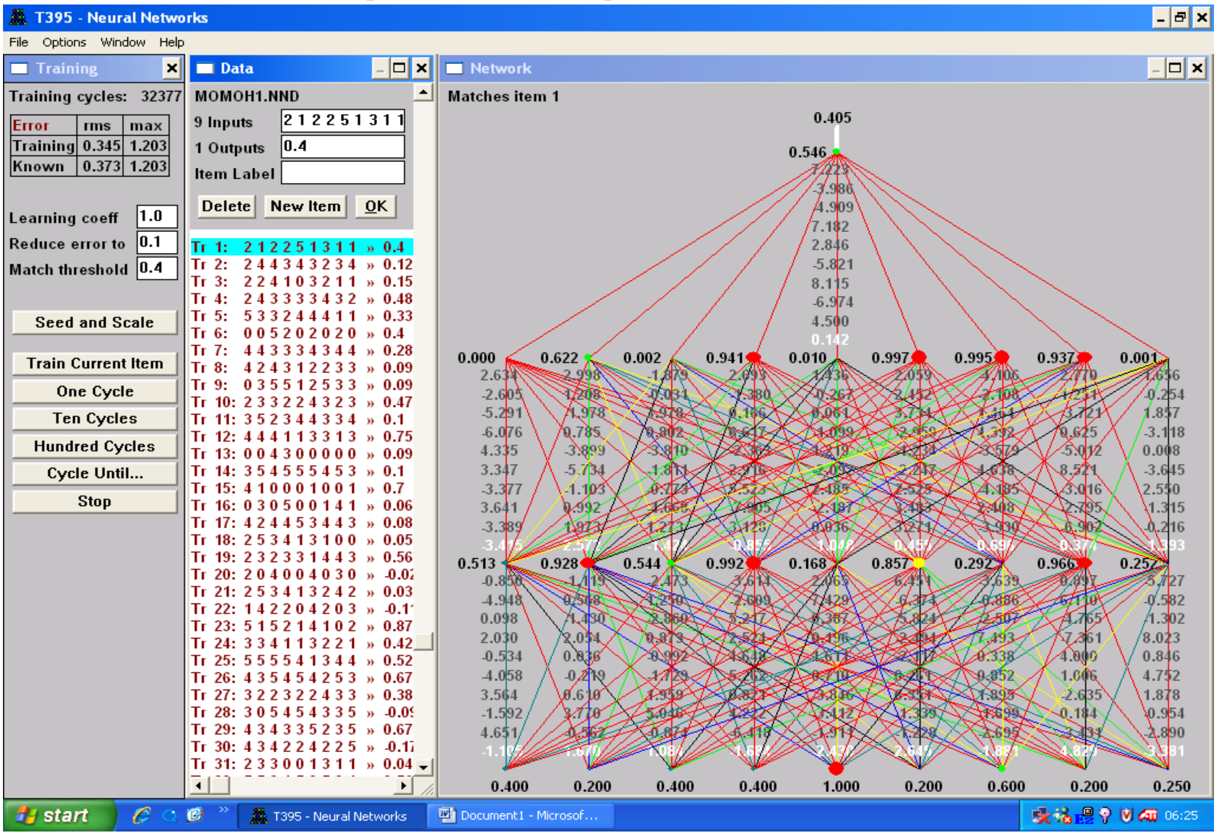
S/No	BC 23	BC 21	BC 13	BC 18	BC 43	BC 9	BC 19	BC 29	BC 20	Actual cost impact (t_j)	Partition
169	5	4	4	4	3	5	2	4	1	0.05	Validation
170	0	0	1	*3*	0	3	3	0	3	0.17	Validation
171	3	3	2	3	2	3	1	2	4	0.11	Validation
172	0	3	4	2	0	5	1	0	3	0.20	Validation
173	5	3	2	1	0	4	3	1	1	0.22	Validation
174	0	4	1	3	5	5	5	3	5	0.53	Validation
175	0	4	2	3	5	2	4	4	3	0.92	Validation
176	5	2	4	3	5	2	2	3	3	0.80	Validation
177	5	3	3	2	4	3	3	3	4	0.58	Validation
178	4	4	2	3	0	1	3	2	3	0.08	Validation
179	3	2	3	1	1	3	2	1	2	0.58	Validation
180	5	5	5	3	5	4	5	5	4	-0.02	Validation
181	1	1	0	1	3	1	1	1	0	0.39	Validation
182	2	2	5	5	0	3	3	4	3	0.32	Validation
183	5	5	1	4	5	1	2	5	2	0.15	Validation
184	2	3	0	1	1	4	0	3	2	0.09	Validation
185	3	3	5	5	4	2	1	2	4	0.75	Validation
186	0	5	2	5	0	3	2	2	1	0.13	Validation
187	4	3	1	3	1	2	3	3	2	0.47	Validation
188	3	2	1	1	5	1	1	2	1	0.33	Validation
189	5	4	1	3	0	0	2	0	4	0.56	Validation
190	2	4	2	4	4	3	5	4	3	0.96	Validation
191	2	4	3	4	5	2	4	3	4	0.24	Validation
192	5	3	5	0	2	3	1	2	2	0.19	Validation
193	0	4	5	3	0	4	3	5	3	0.32	Validation
194	5	4	5	5	0	1	2	3	2	0.10	Validation
195	1	3	4	5	5	3	1	3	2	0.58	Validation
196	5	5	3	5	0	2	5	0	5	0.61	Validation
197	5	5	5	5	4	5	5	2	5	0.14	Validation
198	3	5	5	5	5	5	5	3	5	0.06	Validation
199	4	4	1	1	4	3	2	5	3	0.17	Validation
200	5	2	2	2	1	1	1	0	0	0.11	Validation
201	3	0	3	3	1	1	2	2	1	0.56	Validation
202	3	1	5	4	3	1	2	5	4	0.12	Validation
203	3	3	1	4	1	0	1	2	0	0.04	Validation
204	5	5	5	5	5	0	3	5	1	0.05	Validation
205	3	5	3	4	5	1	5	3	0	0.04	Validation
206	4	0	2	5	4	4	3	3	1	0.04	Validation
207	3	3	3	5	5	1	5	5	4	0.13	Validation
208	5	2	3	5	3	3	1	5	0	0.22	Validation
209	5	1	2	3	4	2	2	4	1	0.12	Validation

APPENDIX XXIII: New dataset for duration impact models validations

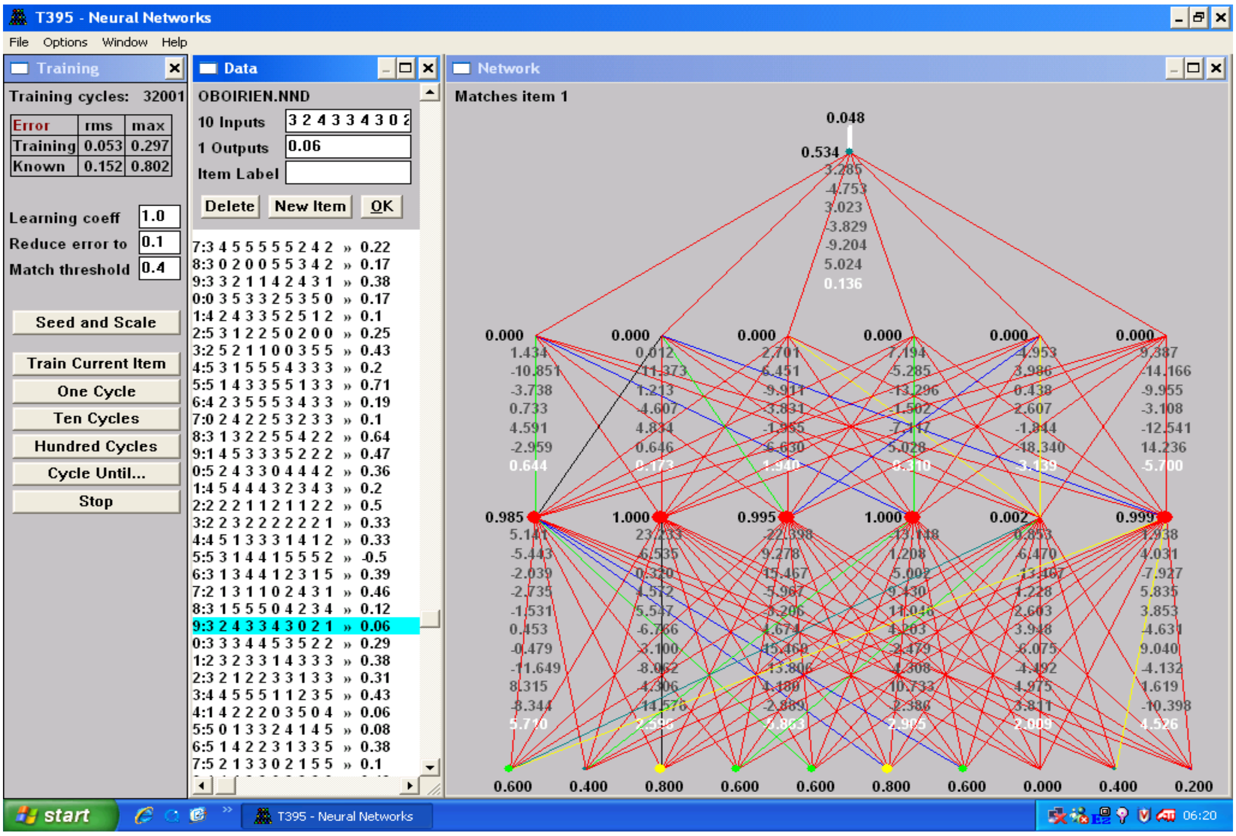
S/No	BT.76	BT.79	BT.71	BT.69	BT.49	BT.92	BT.55	BT.82	BT.75	BT.67	Actual time impact	Partition
161	4	2	4	3	3	5	2	5	1	2	0.10	Validation
162	5	3	1	2	2	5	0	2	0	0	0.25	Validation
163	2	5	2	1	1	0	0	3	5	5	0.43	Validation
164	5	3	1	5	5	5	4	3	3	3	0.20	Validation
165	5	1	4	3	3	5	5	1	3	3	0.71	Validation
166	4	2	3	5	5	5	3	4	3	3	0.19	Validation
167	0	2	4	2	2	5	3	2	3	3	0.10	Validation
168	3	1	3	2	2	5	5	4	2	2	0.64	Validation
169	1	4	5	3	3	3	5	2	2	2	0.47	Validation
170	5	2	4	3	3	0	4	4	4	2	0.36	Validation
171	4	5	4	4	4	3	2	3	4	3	0.20	Validation
172	2	2	2	1	1	2	1	1	2	2	0.50	Validation
173	2	2	3	2	2	2	2	2	2	1	0.33	Validation
174	4	5	1	3	3	3	1	4	1	2	0.33	Validation
175	5	3	1	4	4	1	5	5	5	2	-0.50	Validation
176	3	1	3	4	4	1	2	3	1	5	0.39	Validation
177	2	1	3	1	1	0	2	4	3	1	0.46	Validation
178	3	1	5	5	5	0	4	2	3	4	0.12	Validation
179	3	2	4	3	3	4	3	0	2	1	0.06	Validation
180	3	3	3	4	4	5	3	5	2	2	0.29	Validation
181	2	3	2	3	3	1	4	3	3	3	0.38	Validation
182	3	2	1	2	2	3	3	1	3	3	0.31	Validation
183	4	4	5	5	5	1	1	2	3	5	0.43	Validation
184	1	4	2	2	2	0	3	5	0	4	0.06	Validation
185	5	0	1	3	3	2	4	1	4	5	0.08	Validation

186	5	1	4	2	2	3	1	3	3	5	0.38	Validation
187	5	2	1	3	3	0	2	1	5	5	0.10	Validation
188	1	1	4	2	2	0	2	2	2	0	0.12	Validation
189	2	4	4	1	1	4	3	3	3	2	0.25	Validation
190	2	2	2	3	3	1	1	3	1	1	0.25	Validation
191	1	0	1	0	0	1	1	2	2	3	0.20	Validation
192	4	5	0	5	5	5	4	4	1	4	0.26	Validation
193	1	1	5	5	5	5	3	5	4	2	0.24	Validation
194	1	2	5	0	0	4	3	3	2	2	0.29	Validation
195	3	0	2	0	0	3	0	4	0	5	0.08	Validation
196	3	3	1	3	3	4	3	3	3	3	0.10	Validation
197	2	1	2	4	4	0	5	3	5	5	0.13	Validation
198	1	0	0	3	3	5	3	5	3	5	0.47	Validation
199	5	3	4	5	5	3	0	0	3	3	0.15	Validation

APPENDIX XXIV: Screen dump of the ANN cost impact model



APPENDIX XXV: Screen dump of the ANN duration impact model



Appendix XXVI: Template for assessing dimensions of complexity in construction projects

S/No	The Project	Cost dimensions		Time dimensions		Plant and Equipment content		Other dimensions of complexity (energy, mental and creativity, technology)				
		Initial Contract Sum	Project Final Cost	Estimated Construction Duration	Actual Construction Duration	Heavy duty	Light mechanical hand-tools	Creativity or Innovative potentials	Technical dimension	General health dimensions of the construction site operatives	General Health dimensions of the sectional team leaders	Mental dimensions of the building team overall leader
1	Pakistan Hydro-Electric Project											
2	Canadian James Bay											
3	Trans Alaska Pipeline System											
4	Argentina Centro-Oeste project											
5	Columbia correjon											
6	Stratford platform in North Sea											
7	Australia Cooper Basin Project											
8	Papua New Guinea's huge copper and gold mining complexes											
9	Synthetic fuel plant, South Africa											
10	US Navy development of the Littoral Combat Ship (Karp, 2007)											
11	Channel Tunnel connecting Great Britain and France (Kharbanda and Pinto 1996)											
12	Boston Central Artery Project (USS, 2000; USHOR, 2005)											
13	Denver International Airport	$1.70billion	$4.5billion									

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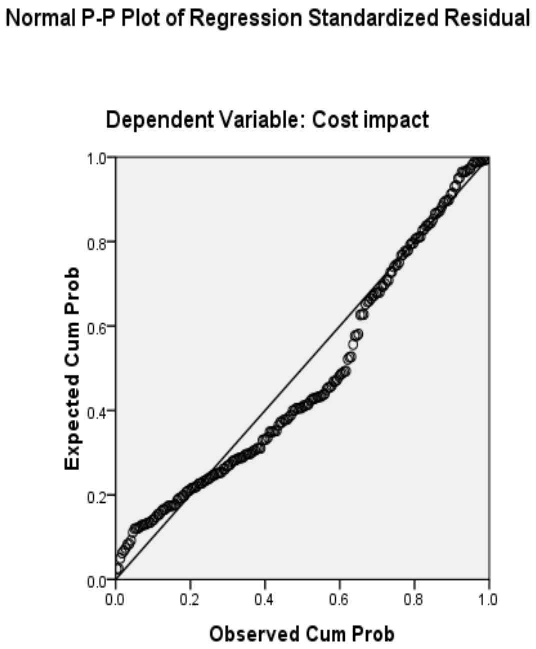
……………………… Signed

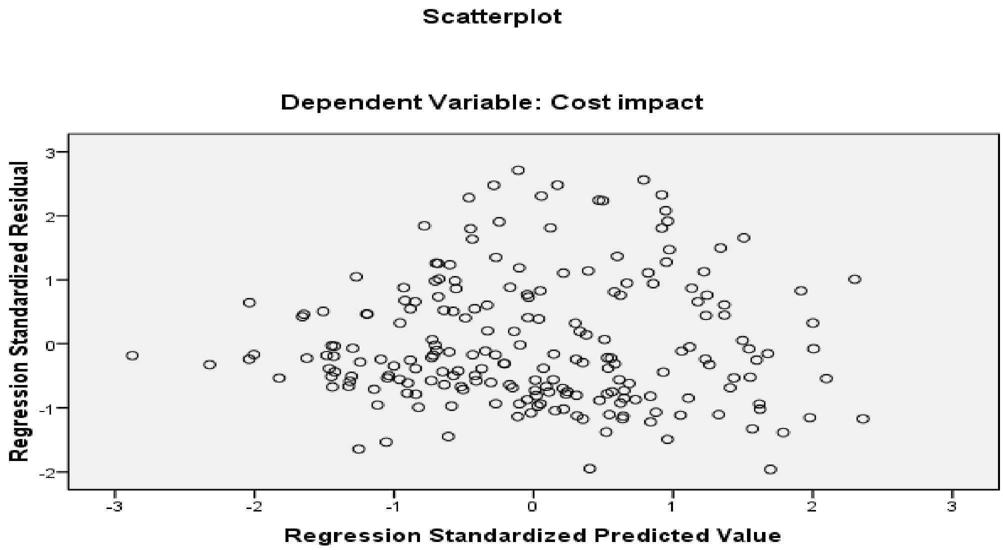
Appendix XXVII: Template for assessing the dimensions of non-complexity in construction projects

Prj	Cost dimensions		Time dimensions		Other dimensions of non-complexity (energy, mental and creativity, technology)					
	Initial Contract Sum	Project Final Cost	Estimated Construction Duration	Actual Construction Duration	Plant and Equipment Content	Creativity or Innovative potentials	Site topography	Technical dimension	General Health dimensions of the construction site operatives	Mental dimensions of the building team overall leader
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										

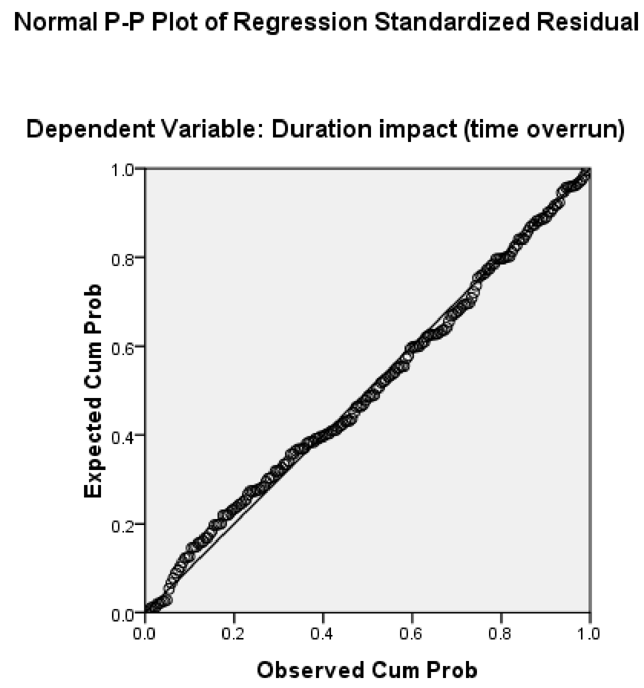
APPENDIX XXVIII: Test results of data satisfaction of multiple linear regression assumptions



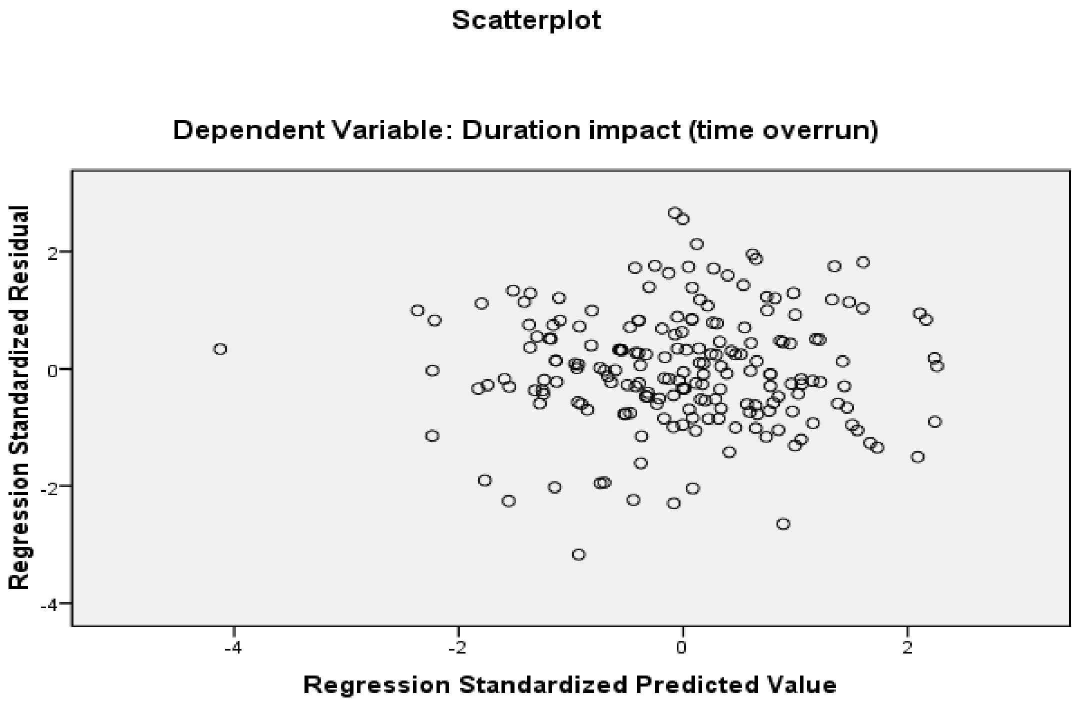
APPENDIX XXVIIIa: Cost impact model Normal P-P plot of regression standardized residual



APPENDIX XXVIIIb: Scatter plot of cost impact model



APPENDIX XXVIIIc: Duration impact model Normal P-P plot of regression standardized residual



APPENDIX XXVIIId: Scatter plot of duration impact mode

APPENDIX XXIX: Some artificial neural network studies and the study areas

Listed artificial neural network researches in the reference column		Non-African study centre	African study centre		Listed artificial neural network researches in the reference column		Non-African study centre	African study centre	
Page number	**Total number of studies**		**Nigeria**	**Others**	**Page number**	**Total number of studies**		**Nigeria**	**Others**
189	1	-	1	-	211	2	2	-	-
190	1	1	-	-	212	3	3	-	-
191	-	-	-	-	213	1	1	-	-
192	1	1	-	-	214	3	3	-	-
193	3	3	-	-	215	-	-	-	-
194	3	-	3	-	216	3	3	-	-
195	1	1	-	-	217	1	1	-	-
196	-	-	-	-	218	-	-	-	-
197	4	4	-	-	219	2	2	-	-
198	2	2	-	-	220	-	-	-	-
199	3	3	-	-	221	-	-	-	-
200	3	3	-	-	222	1	1	-	-
201	2	2	-	-	223	1	1	-	-
202	3	3	-	-	224	-	-	-	-
203	1	1	-	-	225	3	3	-	-
204	2	2	-	-	226	1	1	-	-
205	2	2	-	-	227	1	1	-	-
206	3	3	-	-	228	-	-	-	-
207	-	-	-	-	229	-	-	-	-
208	3	3	-	-	230	1	-	1	-
209	2	2	-	-	231	5	5	-	-
210	1	1	-	-	232	1	1	-	-
					Grand Total	70	65	5 (7.14%)	-

APPENDIX XXX: Comparison of the cost factors by the derivation methods

S/No	By group mean		By factor analysis		By MLR Cost impact model	
	Factor	**Mean**	**Factor**	**Comp. loading**	**Factor**	**Sig.**
1	Contract manager's inexperience	2.96	Payment delays to sub-contractor and supplier	.667	Fraud/corrupt practices	0.002
2	Payment delays to main contractor	2.85	Payment delays to main contractor	.646	Contract manager's inexperience	0.100
3	Unstable foreign exchange	2.80	Contract information delay	.555	Cash flow problems	0.160
4	Variations to works	2.72	Inadequate prime cost and provisional sum	.527	Unstable foreign exchange	0.198
5	Fraud/corrupt practices	2.66	Fluctuation/Inflation of price	.674	Contract information delay	0.354
6	Government's changes in policy and fiscal measures	2.65	Inaccurate cost estimate	.553	Government's change in policy and fiscal measures	0.850
7	Inadequate prime cost and provisional sum	2.64	Design changes	.750	Inadequate prime cost and provisional sum	0.861
8	Cash flow problems	2.63	Changes in specifications	.651	Variations to works	0.862
9	Contract information delay	2.63	Design errors	.567	Payment delays to main to the main contractor	0.895

APPENDIX XXXI: Comparison of the time factors by the derivation methods

S/No	Group mean score		Factor analysis & component loadings		MLR Cost impact model	
	Factor	**Mean value**	**Factor**	**Comp**	**Factor**	**Sig.**
1	Design errors	2.81	Industrial unrest/strikes	**.761**	Payment delays to the main contractor	0.172
2	Cash flow problems	2.72	Delay in the delivery of imported materials	**.661**	Cash flow problems	0.182
3	Payment delays to the main contractor	2.68	Fuel shortage	**.636**	Natural disaster as flood	0.245
4	Contractors' improper contract knowledge	2.66	Civil commotion/community issues	**.774**	Design errors	0.420
5	Delay in drawing preparations	2.63	Lack of relevant tools and equipment	**.662**	Delay in drawing preparations	0.756

	and approval				and approval	
6	Inadequate prime cost and provisional sum	2.62	Political instability	**.638**	Design changes	0.761
7	Design changes	2.61	Insecurity/insurgency	**.628**	Inadequate prime cost and provisional sum	0.775
8	Natural disaster such as flood	2.61	Force majeure	**.613**	Variations to works	0.840
9	Conflict between contractual parties	2.60	Inclement weather	**.730**	Non-performance of subcontractors	0.932
10	Non-performance of subcontractors	2.59	Bureaucracy in client's organization	**.602**	Contractor's improper contract knowledge	0.956

APPENDIX XXXII: Responsibilities of the contractual parties for management of cost and time factors

S/No	Cost		Time	
	Factor	Party	Factor	Party
1.	Payment delays to main contractor	Client^{c}	Payment delays to main contractor	Client^{c}
2.	Inadequate prime cost and provisional sum	Consultant^{cons}	Inadequate prime cost and provisional sum	Consultant^{cons}
3.	Cash flow problems	Client^{c}/Contractor^{ct}	Cash flow problems	Client^{c}/Contractor^{ct}
4.	Variations to works	Client^{c}	Variations to works	Client^{c}/
5.	Contract manager's inexperience	Contractor^{ct}	Design errors	Consultant^{cons}
6.	Unstable foreign exchange	Economic	Delays in drawing preparation and approval	Client^{c}/Consultant^{cons}
7.	Contract information delay	Consultant^{cons}/Client^{c}	Contract information delay	Consultant^{cons}/Client^{c}
8.	Fraudulent/Corrupt practices	Client^{c}/Contractor^{ct}/Consultant^{cons}	Natural disaster	Act of God
9.	Government's change in policies and fiscal measures	Political/Economic	Design changes	Consultant^{cons}
10.			Non-performance of subcontractor	Contractor^{ct}

Appendix XXXIII: Altshuler and Luberoff (2003) construction project complexity classification translations to the 2018 Nigeria Naira value

Project Complexity Class	**Conversions to 2018 Nigeria Naira (N billion)**	**Altshuler and Luberoff's (2003) and Randolph et al. (1987) in United States of America project size Dollar ($million)**	**No of projects per class**
Uncomplicated	< 5.18	< 50	206
Medium or moderately complex	5.18 ↔25.90	50 ↔ 250	30
Largely complex	25.90 >	250 >	10