MODELING DURATION OF BUILDING RENOVATION PROJECTS

BY

Haruna Sa'idu, LAWAL

(P18EVQS8008)

DEPARTMENT OF QUANTITY SURVEYING,

FACULTY OF ENVIRONMENTAL DESIGN,

AHMADU BELLO UNIVERSITY,

ZARIA, NIGERIA

AUGUST, 2021

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A DESSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY, IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF MASTER OF SCIENCE DEGREE IN PROJECT MANAGEMENT

DEPARTMENT OF QUANTITY SURVEYING,
FACULTY OF ENVIRONMENTAL DESIGN,
AHMADU BELLO UNIVERSITY,
ZARIA, NIGERIA

AUGUST, 2021

Dedication

This dissertation is dedicated to my mother, Malama Hauwa Haruna Makarfi and my father, Professor Lawal Sai'du Makarfi.

Declaration

I declare that the work in this dissertation entitled **"MODELING DURATION OF BUILDING RENOVATION PROJECTS"** has been performed by me in the Department of Quantity Surveying under the supervision of Dr. Hassan Ahmadu and Dr. Muhammad Abdullahi. No part of this dissertation was previously presented for another degree or diploma at this or any other University. The information derived from the literature has been duly acknowledged in the text and a list of references provided.

_____	_____	_____
Name of Student	Signature	Date

Certification

This thesis entitled **"MODELING DURATION OF BUILDING RENOVATION PROJECTS"** by Haruna Sai'du Lawal, meets the regulations governing the award of the degree of Master of sciene of Ahmadu Bello University, Zaria, and is approved for its contribution to knowledge and literary presentation.

_____ _____

Dr. H. A. Ahmadu Date

Chairman, Supervisory Committee

_____ _____

Dr. M. Abdullahi Date

Member, Supervisory Committee

_____ _____

Dr. B. A. Kolo Date

Head of Department

_____ _____

Prof. S. Abdullahi Date

Dean, School of Postgraduate Studies

Acknowledgement

All praise is to Allah (S.W.T) for making it possible for me to successfully complete my M.Sc in Project Management.

I am really gratefull for the support, supervision, friendship, mentorship and encouragement of my supervisors: Dr. H. A. Ahmadu and Dr. M. Abdullahi, you really did more than your job.

I am also indebted to the entire staff of Quantity Surveying Department, Ahmadu Bello University Zaria especially Dr. B. A. Kolo, Prof. Y. M Ibrahim, Prof. A. D. Ibrahim, Dr. M. Abdulrazaq, Prof. K.J. Adogbo and Dr. A.A. Ali without whose support and inspiration this research would not have been completed.

My family the best cheerleaders ever, I really appreciate your support and encouragement.

I am grateful for the support and prayers of my friends especially Yamusa. M. A and Dandago A.A.

ABSTRACT

Accurate estimation of construction time has been identified as a major problem to the construction industry at large, several efforts have being made to develop models to predict duration of construction projects, researchers argued that development of models to predict duration of renovation projects is in its preliminary stage and went on to develop a model to predict duration of renovation projects. Existing models are scope based model and researchers have questioned the accuracy of scope based models as they do not include other non-scope factors which affect duration of projects. This study is aimed at developing a model which incorporate both scope and non-scope factors in predicting duration of building renovation projects. To achieve this aim, non-scope factors as well as project scope factors with good predictive abilities were firstly, identified from literature. A questionnaire survey was then used to obtain from construction firms; basic data/information relating to the identified project scope factors as well as data/information relating to impact of the non-scope factors on duration of building renovation projects. Out of a computed sample size of 357 TETfund building renovation projects, data relating to 121 completed TETfund building renovation projects were provided by the construction firms. Descriptive statistics was used to gain an overview of data obtained from the questionnaire survey, the study revealed that the most significant factors that affect duration of building renovation projects are variations, incomplete scope of work, material delivery, scarcity of materials, labour productivity, and owner financial capacity are the top five factors that influence duration of renovation projects. inferential statistics was used to determine the variance in duration of different categories of renovation projects and the ANOVA shows that statistical significant difference exist in duration of different types of renovation projects. 90% of the data was used to develop an artificial neutral network models on SPSS25. MAPE and T-Test were used to validate the models. 8 Artificia Nuera Network models were developed one multilayer perceptron (MLP) and radial basis function (RBF) model for each category. The accuracy of the models are 86%, 80%, 90%, 87%, 91%, 87%, 98%, 96% in this other; MLP(General), RBF(General), MLP(Block of offices and classroom), RBF(Block of offices and classrooms), MLP(Library), RBF(Library), MLP(Theatre), RBF(Theatre). The developed models will help project managers to accurately predict the duration of building renovation projects.

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CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Construction duration was defined by Bokha (1998) as the time frame given by the owner to the contractor to finish the project under normal working conditions. Construction duration is an important basis for measuring the total performance of construction project hence, it must be correctly estimated at preliminary stage (Love, Tse and Edwards, 2005). Wrong estimation of project completion time, whether under or overestimation causes poor project performance and failure of meeting project aim and objectives as expected (Khosrowshahi, 1996; Kaka 1996; Lin, Tserng, Ho and Young, 2011; Jin, Han, Hyun and Cha 2016). These afore mentioned assertions made accurate construction time estimation very vital to both client and contractor, as such, several methods to estimate construction duration exist.

Traditional methods such as; meticulous analysis of work to be done and resources available using estimates of the time rations for each specific task. (Federal Highway Administration FHWA, 2010); deducting from the client's brief and available project information Nkado (1995) as well as; use of average output rates for all resources allocated to an activity Lana (2006); Youssef, El-Dash and Ramadan (2013), were the methods first used to predict construction time. However, as discovered by Skitmore and Ng (2003), the high level of bias and the time needed when using these approaches compelled the development of swift, user friendly statistical/mathematical models to predict construction time. This created a paradigm shift in the prediction of construction duration.

The first mathematical model to predict construction duration was developed by Bromilow (1969) for building projects in Australia. The model comprises two variables only namely time and cost. Since then, several efforts have been made to validate Bromilow's time-cost model (Bromilow *et al.*, 1980; Kaka and Price, 1991; Yeong, 1994; Kumaraswamy and Chan, 1995; Chan 1999, Choudry and Rajan, 2003; Long and Young, 2009; Ogunsemi and Jagboro 2006; Ameyaw *et al*., 2012). Researchers have questioned the precision of these project scope-based models and have detected that they lacked the inclusion of several other non-project scope (qualitative) factors which impact construction duration (Walker, 1995; Chan, 1999; Ng *et al.*, 2001).

Research works have also been conducted to develop multivariate construction time predicting models combining project scope (quantitative factors) and other non-project scope factors (qualitative factors) (Chan and Chan, 2002; Hoffman *et al*., 2007; Ahmadu *et al., 2015*). However, owing to Kaka and Price (1993)'s observation that poor classification of projects has been indicated to be one of the main reasons for the unsuccessful results of some previous models. Studies have been executed to develop models for specific type of construction projects.

Koo, Hong, Hyun and Koo (2010) developed a case-based reasoning hybrid model for multi housing building estimation construction cost and time. Jin *et al.* (2016) also developed a case-based reasoning model for estimating duration of multi housing projects. Kim, Yeom and Kim. (2018) developed a model for general office buildings. Czarnigowska and Sobotka (2013) developed a mathematical model to predict duration of road projects in southwestern Poland. However, estimating the project duration has been limited to the new construction, and relevant research on renovation construction is in its preliminary stage (Yoon, Jung, & Yu, 2017).

Renovation is a complex process and is highly uncertain (Thuvander *et al*., 2012) so the normal project duration of renovation cannot be generalized.

Renovation projects are generally more uncertain than other construction projects (Quah 1988, Rogers and Mansfield, 2001). Saleh (2009) revealed that renovation project is a more difficult task compared with new buildings, he further asserted that renovations are characterized with inaccurate scope of works. The main characteristic that influence the complexity of renovation projects is the concurrent utilization of a building by both workers and users (krizek *et al.*, 1996). The renovation processes are uncertain in terms of decision-making, planning, and execution compared to the process of new construction (Thuvander *et al.,* 2012). The aforementioned findings led to the development of model for renovation works by (Yoon and Yu, 2019).

1.2 Statement of Research Problem

The model developed by Yoon and Yu (2019) considered only scope (quantitative) factors affecting duration thereby neglecting no-scope (qualitative) factors which affect construction duration , political factors, environmental factors, client factors, financial factors etc. Researchers have questioned the accuracy of these project scope-based models and have rightly observed that they lacked the inclusion of several other non-project scope (qualitative) factors which influence construction time (Walker, 1995; Chan, 1999; Ng *et al.*, 2001). Ahmadu *et al.,* (2015) discovered that incorporating these qualitative factors in model development improves the accuracy of the model. As no attempt exist to incorporate both scope and non-scope factors in prediction duration of building renovation projects, a gap in existing body of knowledge is established.

1.3 Aim and Objectives

1.3.1 Aim

The study aims to model the duration of building renovation projects.

1.3.2 Objectives

The objectives of this research are to:

a) To asses qualitative factors influencing duration of building renovation projects.

b) Develop a model for predicting duration of renovation works for building projects.

c) Validate the model.

1.4 Significance of Study

The development of a model for predicting duration of building renovation projects will help both client and consultants to achieve project objective of completion within stipulated time by predicting the accurate time it will take to complete a building renovation project, this will help save cost and obliterate dispute that arise as a result of duration overrun.

1.5 Scope and Limitations

1.5.1 Scope

The model incorporate scope and non-scope factors which affect duration, owing to the assertion by Kaka and Price (1993) that poor classification of projects is the reason for failure of several models, this study will only considered renovation projects funded by TETFUND completed within 2015-2020 in Nigeria.

5.1.2 Limitations

1. The usefulness of the models developed in this study is limited to the accuracy of the data provided by respondents in the questionnaire survey.

2. Prediction is only valid within the range of characteristics of the selected sample data. Hence, it will only be applicable to projects with such characteristics.

3. The neural network used for prediction has its limitations as well- the primary limitation being that the process involved in the prediction of the outputs are not presented as mathematical formulas, but in a “black box” manner. The knowledge of how weights are attached to the predictors and subsequent generation of the predicted is not available to the user of the model.

CHAPTER TWO

LITERATURE REVIEW

2.1 Identification of Factors Affecting Construction Time

Bhokha (1998) defined construction duration as the time frame given by the owner to the contractor to finish the project under normal working conditions, normal practice of construction, and based on the minimum costs. It starts when the contractor receives the instruction to proceed and ends at the completion of construction works on site. Construction duration is affected by several factors which leads to time overrun, it also includes delays caused by unanticipated circumstances, e.g. alteration of works (changed conditions and change orders), extra works, and supply of materials, location, weather, and site work conditions. The importance of timely completion of construction projects, direct and indirect costs associated with delays have inspired many researchers to study the factors affecting construction duration/ factors causing delay.

Time overruns is defined as the extension of time beyond planned completion dates traceable to the contractors (Kaming *et al* 1997). Choudhry (2004) and Chan (2001), defined time overruns as the difference between the actual completion time and the estimated completion time. Delays in project are those that cause the project completion date to be delayed (Al- Gahtani and Mohan 2007). Many factors related to time overruns vary along with types of project, location, size and scope of project. Time and cost increase is common phenomenon in projects worldwide.

Kaming *et al*. (1997) identified 11 variables of time overruns and 7 variables of cost overruns through questionnaire survey in Indonesian high rise construction projects. Design changes, poor

labor productivity, lack of adequate planning, shortage of materials and inaccuracy of material estimates are the five causes of time overruns.

Chan and Kumaraswamy (1997) reported five principle causes of time overruns perceived among contractors, clients and consultants in Hong Kong construction projects. Data was collected through questionnaire survey comprising 83 delay factors across eight categories and distributed to 400 local firms involved in construction activities. Based on 37% response, the five most significant factors of delay revealed were poor site management and supervision, unforeseen ground conditions, delay in decision making, client initiated variations and design changes.

Delays in Turkey were first studied by Arditi, Akan and Gurdamar (1985) which concluded that in 1970s the main causes of delay in the publicly funded construction projects in Turkey were shortage of construction material, late payments and contractor defects. Another study on the causes of delay in construction projects in Turkey was conducted by Gündüz, Nielsen and Özdemir (2013) which identified 83 delay factors in nine major categories. Gündüz *et al.* (2013) Stressed that important causes of delay in Turkey, consisted of 15 factors including inadequate contractor experience, ineffective project planning, poor site management and change orders.

In Hong Kong, the main causes of delay and cost overrun in construction projects were identified as poor site management, unforeseen ground conditions, poor decision making and change orders (Chan and Kumaraswamy, 1997; Chan and Kumaraswamy, 2002). Le-Hoai, Dai Lee and Lee (2008) studied the causes of delay in several countries and compared them with the factors in Vietnam. Accordingly, lack of experience, design inefficiencies, poor cost estimates,

financial capabilities, government and labour incompetence were identified as the most important delay factors in Vietnam.

In Thailand, on the other hand, the most important causes of delay in construction projects were described as resource and labour shortages, inefficient contractor management, poor design, poor project planning, change orders and financial difficulties (Toor and Ogunlana, 2008). Alaghbari *et al*. (2007) found that financial and coordination problems as the most important delay factors in Malaysia. Hamzah *et al*. (2012) identified several factors including labour productivity, material delivery, inflation and insufficient equipment as delay factors in Malaysia.

According to Abdul Kadir *et al*. (2005), the most important delay factors were shortage of material, late payments to suppliers, change orders, late submission of drawings and poor site management. Sambasivan and Soon (2007) described 10 reasons including improper planning, poor site management, lack of experience, late payments, problems with subcontractors, labour supply and shortage of material as the most important delay factors in Malaysian construction projects. Abdullah *et al*. (2011) studied the causes and effects of delay in large MARA construction project based on the perception of Project Management Consultants (PMC) in Malaysia. As asserted by the study, the 5 most significant causes of construction delay were cash flow and financial difficulties faced by contractors, contractor's poor site management, inadequate contractor experience, shortage of site workers, and ineffective planning and scheduling by contractors.

Alghbari *et al*. (2007) examined the factors that cause delay in Malaysian construction projects, the study discovered that the major factors that influence construction duration are factors due to contractors, factors due to consultants, factors due to owners and finally external factors. Among

the aforementioned factors, the study identified that the financial factor is the most influencing factor in causing delay in Malaysian construction projects. This is however an obvious fact as construction works cannot proceed without finances.

Doloi *et al*. (2012) identified the key factors impacting delay in Indian construction industry and then established the relationship between the critical attributes for developing prediction models for assessing the impacts of these factors on delay. Regression modeling and Factor analysis were used to examine the significance of the delay factors. The most critical factors of construction delay were identified as lack of commitment, inefficient site management; poor coordination in site, improper planning, lack of clarity in scope of project, lack of communication from factor analysis. Regression model indicates slow decision from owner, poor labour productivity, architects reluctance for change and rework due to mistakes in construction are the reasons that affect the overall delay of the project.

Aziz (2013) identified 99 factors that caused time overrun were identified and these factors were categorized into 9 major groups. Furthermore, the most 3 significant factors for each group was found. They were: (1) Contractor category : ineffective project planning and scheduling, poor site management and supervision, poor financial control on site, (2) Equipment category: shortage of equipment, frequent equipment breakdowns, equipment allocation problem, (3) Owner category: delay in progress payments, selecting inappropriate contractors, inadequate planning, (4) Project category: complexity of project, legal disputes between project participants, ineffective delay penalties, (5) Design category: design changes by owner, misunderstanding of owner's requirements by design engineer, design errors and omissions made by designers, (6) Consultant category: delay in approving major changes in scope of work by consultant, lack of

consultant experience in construction projects, poor communication and coordination between owner and contractor, (7) External category: different tactics patterns for bribes, sudden failures actions, global financial crisis, (8) Material category: shortage of construction materials, late delivery of materials, delay in manufacturing materials, (9) Labour category: unqualified/inadequate experienced labour, shortage of labour, and low productivity of labour.

Marzouk and El-Rasas (2013) outlined the top ten causes of delay in Egyptian construction projects. It comprised finance and payments of completed work by owner, variation orders/changes of scope by owner during construction, effects of subsurface conditions, low productivity level of labour, ineffective planning and scheduling of project, difficulties in financing project by contractor, type of project bidding and award, shortage of construction materials in market, late in revising and approving design documents by owner, and unqualified workforce.

Pai and Bharath (2013) studied the causes of delay in Indian infrastructure project and found 73 causes and has classified them into nine groups. Three critical causes of delay were identified for each group which were (1) Project group: original contract duration is too short, legal dispute between various parties, and type of construction contract, (2) Owner group: delay in progress payment by owner, late revision and approval by owner, and delay in giving site to contractor, (3) Contractor group: ineffective planning and scheduling, difficulty in financing by contractor, and delay in subcontractor work, (4) Consultant group: late revision and approval by consultant, poor communication, and inflexibility of consultant, (5) Design group: mistakes and discrepancies in design document, unclear and inadequate details in drawings, and complexity of the project design, (6) Material group: delay in material delivery, shortage of material in market,

and changes in material type and specification, (7) Equipment group: equipment breakdown, shortage of equipment on site, and low level skill of operator, (8) Labour group: Shortage of labour, unqualified work force, and low productivity, (9) External group: effects of subsurface condition, delay in getting permit from municipality, and rain effect on site.

Amu and Adesanya (2011) studied the factors that contributed to time overrun in Nigerian construction project. The result showed that funding and payment, contractor and client factors were the major factors that contributed to the delay of projects. Aibinu and jagboro (2002) examined the effects of delay on the delivery of construction projects in Nigeria. Acceleration of site activities coupled with improved owner's project management procedures and inclusion of an appropriate contingency allowance in the pre contract estimate were recommended as a means of minimizing the adverse effects of construction delays in Nigeria. Odeh and Battaineh (2002) studied the causes of construction delay at traditional contracts in Jordan. The study illustrated that labour productivity was the most important delay factor according to contractors, inadequate contractor's experience, however was the most important delay factor to consultants.

Koushki *et al*., (2005) identified estimates of time and cost overruns and their causes. The three main causes of time overruns are changing orders, owner's financial constraints and owner's lack of experience Gündüz *et al*., (2013) conducted a survey on Turkey construction projects to identify the delay factors. 83 delay factors were identified and categorized into 9 major categories. Results of their study indicated that the most significant factors were inadequate contractor experience, ineffective project planning and scheduling, poor site management and supervision, design change by owner, late delivery of materials, unreliable subcontractors, delay in performing inspection and testing, unqualified workers, change orders, delay in site delivery, delay in approving design documents, delay in progress payments, slowness in decision making,

poor communication and coordination with other parties, and unexpected surface and subsurface conditions.

Fugar and Agyakwah-Baah (2010) conducted a study to investigate the causes of delay in building construction projects in Ghana through interviews and questionnaires survey. A total of 32 causes of delay were analyzed and the top ten influencing factors in causing delay were delay in honoring certificates, underestimation of the costs of projects, underestimation of the complexity of projects, difficulty in accessing bank credit, poor supervision, underestimation of time for completion of projects by contractors, shortage of materials, poor professional management, fluctuation of prices, and poor site management.

Frimpong *et al*. (2003) carried out a questionnaire survey in Ghana groundwater construction projects and ranked 26 factors responsible for project delays and cost overruns. The Kendall's coefficient of concordance was used to test the degree of agreement between owner's, contractors and consultants and concluded that there was insignificant degree of disagreement. Hasan *et al*. (2014) identified the delays in road projects in Bahrain. A total of 47 causes were identified and the result indicated that main causes of delay related to contractors, owners and consultants were improper planning and scheduling, delay in decision making, and lack of experience respectively. While, time and cost overruns were found as the most frequent effects of delay

2.2 Factors Affecting Construction Duration

2.2.1 Cost

The first duration estimation model was Bromilow‟s time-cost model (1969). Many of the researchers have used cost parameter in their models as variable influencing construction duration. (eg Chan and kumaraswamy, 1995: walker, 1995: Bousbaine, 2001: Khosrowshahi and Kaka, 1996: Skitmore and Thomas, 2003: Chen and Huang, 2006: Bhoka and Ogunlana, 1999: Ogunsemi and Jagboro, 2006: Hofmann *et al.,* 2007: Helvaci 2008: Ahmadu *et al*., 2015).

Although many researchers have stated that cost is an important factor in construction duration determination, Love *et al*., (2005) stated that cost is a poor indicator according to their studies. Goren (1998) stated that using the qualitative workmanship for preventing delays could cause increase in cost. Furthermore, when total project duration increases, general overhead cost also increases thus, an increase in construction cost.

2.2.2 Procurement

Goren (1998) and Karsle (1998) pointed out that the importance of procurement related factors on project duration. They stressed that either the owner or the contractor takes care of procurement, not only the materials but the workmanship should be provided on time for the continuation of works. The aim is that the right amount of materials should be provided in good condition in the right place at the right time in order to achieve good work progress. It can be possible with a proper procurement plan.

Sarc (1995) reported procurement factors affecting construction duration which are as follows:

1. Delayed procurement of materials (15.5%)
2. Materials procurement being not according to specifications (6%)

3. Non-availability or requisite manpower with proper skill (45%)

4. Non-availability of appropriate equipment at the right time (25%)

5. Inadequate facilities as: (2%)

a. Supply of water, electricity etc.

b. Sufficient housing for works

c. Recreational facilities

d. Cafeteria near site.

2.2.3 Project Related (Height Of Builing, Number Of Floors, Gross Floor Area And Type Of Building)

Nkado (1995), Sarc (1998), Bhoka and Ogunlana (1999) and Chan and Kumaraswamy (2002) stressed the importance of building size, height of building and number of floors as important factors affecting construction duration. When the building size (gross floor area) increases, the construction duration will be longer. The reason is being that the size of the building affects the system of construction, choice of materials that will be used and procurement system and technology that will be used. Nkado (1995) argued that complexity of project affects the duration. Karsle (1998) stated that complexity of building is related with the project type. E.g. construction of a town hall will be faster than that of a lecture theatre.

2.2.4 Cash Flow

Government, who is the biggest construction client make a yearly payment plan of the project by using cost and duration estimations. Payment for construction works is made to the contractor(s) at designated time intervals, Gören (1998) if there is any insufficiency of cash flow exists, it may cause long-term unfinished construction projects or changing of hands to finish the project. If contractor is financially strong, he can continue to finish the work in the contract period by using

his own finance as much as possible until he receives payment. He tries to continue his work without any interruptions. It causes delays in the work schedule and lost time. Contractors aiming to make profit can even lose money (Gören, 1998). Karslı (1998) stated that delays occur in more than the half of the projects that are run by housing cooperatives because of financial problems. Additionally, Gören (1998) explains the importance of right cost estimation on project duration. If cost estimation is wrong, investment will be insufficient and additional finance will be required. This unexpected financial problem can cause the interruptions or even stop the works.

2.2.5 Productivity of on-site

Productivity is important in all parts of the projects for all parties, for all employees. Especially on-site productivity affects the construction directly. Man-hours used in planning phases define the total construction duration. If the productivity of the workers decreases, it directly affects the speed of the construction works. Chan and Kumaraswamy (1995-1998), Gören (1998), Karslı (1998), and Nkado (1995) define productivity as overall construction (site) productivity, and labor productivity. Chan and Kumaraswamy (1995) analyzed productivity as micro factors (such as construction site productivity) besides macro factors (project-specific characteristics such as building construction costs, gross floor area, and number of levels).

Chan and Kumaraswamy (1998) added that lowered productivity could contribute significantly to project delays. Chan and Kumaraswamy (1998) and Nkado (1995) listed factors affecting site productivity such as work space availability, attendance of operatives, learning curve, weather, labor relations, project complexity project buildability, foundation condition and effectiveness of supervision. Karslı (1998) indicated that problems about productivity could be seen mostly in

developing countries. The labors coming from rural areas have low salaries, which lowers productivity rates below expectations. The solution is to find out the causes affecting productivity negatively and improve conditions to motivate employees such as: over-time pay, contribution for the special works, social activities, and to provide better living and working conditions (Kumaraswamy and Chan (1998); Karslı (1998) and Gören (1998)).

2.2.6 Technology and Methodology of Construction

Gören (1998) stated that usage of new technology, machinery, and materials causes increase in production rates and high quality products by arranging times effectively and reducing lay-off times. There are three types of construction technique. First type is low-tech (manual technique) which is based on workmanship; most of the main works are constructed on site. Hence, labor productivity gains importance. Second type is medium-tech (mechanized technology) which is used to decrease construction durations or to increase the construction speed; for example, using sliding forms to reduce construction time. Third type is high-tech (prefabricated building technique) where components of the building are produced beforehand and then erected on-site, thus, minimizing the duration. (Gören, 1998.) Karslı (1998) also arrived at the same conclusions as Gören (1998) that the projects with minimum delays use developed conventional techniques or prefabrication techniques. The method of construction affects the construction duration significantly, for example if 20 meter height wall is built, there is only way to build this wall i.e. bottom up.

2.2.7 Experience

Walker and Vines (2000), Saraç (1995), Gören (1998), Karslı (1998) emphasize the importance of experience on duration. Experience on similar projects reduces errors and so decreases or even totally eliminate reworks, hence reducing the total construction duration. Karslı (1998) described

the importance of client experience. Especially clients of commercial projects know what their requirements are, so they can give their decisions quickly because of the repetitions of their works. The author also added the importance of contractor's experience. If the contractor has executed similar projects before, he is familiar with the works and does not repeat mistakes. This leads to shortening of the duration Karslı (1998) and Gören (1998) pointed out that the experience of team members with different parties for design, construction, or management group is valuable in reducing delays. Walker and Vines (2000) studied on factors affecting construction durations of multi-unit housing projects in Australia. The authors found experience as an important factor besides, management quality, environmental factors, and coordination.

2.2.8 Coordination

In every sector, communication between all parties has an important role for the progress of work. Especially in the construction sector, there are many parties coming together for the completion of the project, communication management is critically important between the design team, construction team of contractor subcontractor and consultant firms, suppliers, management teams, and the client's agent. It also affects the motivation of all the employees. Nkado (1995), Chan and Kumaraswamy (1999-2002), Karslı (1998) and Walker and Vines (2000) emphasized the importance of the development of coordination between these various agencies involved in the construction for construction duration estimation.

2.2.9 Weather

Local weather conditions determine the duration also as working periods are defined according to seasonal conditions. For example, if a project starts in Ankara in December, the actual construction of this project will most probably start after 3 to 4 months. Saraç (1995), Kaming

(1997), Karslı (1998), Gören (1998), Dissanayaka and Kumaraswamy (1999), Walker and Vines (2000), Chan and Kumaraswamy (2002) all agree that weather conditions affect construction duration. Gören (1998) states that bad weather can interrupt or abort the works; cause decrease in production rate and quality of works, so the work has to be done again. This kind of delays cause increase in cost since labor and equipments lay idle. The author pointed out that if the weather effects are taken into consideration properly while preparing the working schedule, these losses can be prevented.

2.2.10 Construction Site

Chan and Kumaraswamy (1995), Saraç (1995), Gören (1998), Karslı (1998) and Bhokha and Ogunlana (1999) all state that the location of a building has a significant effect on construction duration, i.e. whether or not restrictions or easements exist, and if availability of services, supply of resources, use of major equipment and productivity on site, the accessibility to the site exists. Moreover, construction site conditions, e.g. topography, ground conditions, and the size of the construction site also affects the duration of construction. For example, according to the site conditions, different machinery will be required for either excavations or back fills; these additional steps can cause delays or the large size of the site can decrease the speed of constructions. Finally, no matter what size of construction the required construction site arrangement should be done in a logical way, i.e. site office, storage, shelter for labors, dining hall, etc. should be arranged to facilitate transportation (optimum duration for vertical and horizontal transportation between storage, site and supplier). Karslı (1998) and Saraç (1995) state that all the decisions are given according to the location of the project: whether a project is in the country or abroad. The condition at location requires a detailed analysis for executing the work; e.g. economic and commercial, such as, interest rate, exchange rate, personnel wages, material

costs; social and cultural; legal-political, e.g., traditions, legal and religious holiday and working hours; and technical, etc.

2.2.11 The Degree of Completeness of Design Project

Nkado (1995), Gören (1998), Saraç (1995), and Karslı (1998) agreed that the degree of completeness and precision of project information is very important for project duration. Firstly, this can be affected from the design changes. Any changes in the original design may not be communicated to construction site. This affects construction resource program, cash flow, and material procurement program, therefore, uncertainty of projects can cause delays. Secondly, the details should be completed in project stage for the continuation of project. Finally, the project should meet with the requirement of client. Saraç (1995) explained the reasons of completion ahead of the schedule, although this situation exists rarely. These are summarized factors affecting construction duration also as follows:

1. The urgency from the client's side
2. The bonus announced by the client
3. Higher safety factor in the allocation of time
4. Procurement of material on or ahead of schedule
5. Previous experience in similar projects
6. Use of modern machinery
7. Employment of more than the estimated number of skilled workers
8. The number of workers employed was the same as that of estimated one, but the level of skill was higher than average.
9. The number of workers employed was less that of the estimated one, but the level of efficiency was much higher

10. The size of the project was reduced

11. The design and drawings were simplified before or during construction

12. Effective coordination of different activities

13. High motivation due to harmonious supervisor and worker relationship

2.2.12 Financial Difficulties

According to Alaghbari *et al*. (2007), El-Razek *et al*. (2008), Sweis *et al*. (2008), and Tumi *et al*. (2009) "financial difficulties" are the main factor affecting delay in the construction time. Abdul-Rahman *et al*. (2011) suggested some possible solutions in reducing the financial-related delay such as to structure the market, not to over develop, to conduct training on cash flow management, to access risk management, to be smart in accepting the contract, to choose a good paymaster, and to apply payment bond with bank and client.

2.2.13 Unforeseen Ground Condition

Chan and Kumaraswamy (2002) identified unforeseen ground conditions as causing extensive delays to projects after work commencement on site. Sambasivan and Soon (2007) also stated that unforeseen ground condition was one of the most significant causes of construction delays.

2.2.14 Poor Organisation of the Contractor/Consultant

Poor organisation of the contractor/consultant leads to a construction delays. Studies such as Sambasivan and Soon (2007), Alaghbari *et al*. (2007), Chan and Kumaraswamy (2002), Fugar and Agyakwah-Baah (2010), Sweis *et al*. (2008); Tumi *et al*. (2009) found that, poor organisation or poor management were the most critical factors according to their results. To overcome this delay factor, there are no straightforward solutions to the poor organisation of the contractor/consultant in the construction projects. As suggested by Hao *et al*. (2008), the

construction industry needs an effective construction change management process in order to effectively minimise the impacts to the changes in construction projects.

2.2.15 Poor Communication

Regardless of magnitude, any problem with communication can lead to severe misunderstanding and therefore, delays in the execution of the project. Studies such as Sambasivan and Soon (2007) and Tumi *et al*. (2009) indicated that inadequate communications among all project parties was an important reason for delays in the projects, which impeded the job and resulted in problems in the project coordination and schedules.

2.3 Modelling Construction Duration

Bromilow was the first to establish a relationship between time and cost in Australia. In a survey of 370 construction projects in Australia, Bromilow (1974) developed a mathematical model which predicted construction duration T = KCB, where T is the duration of the construction period from date of site possession to practical completion, in working days, C is the final cost of building, K is a constant describing the general level of time performance and B is a constant describing how the time performance is affected by project size, as measured by cost. His model is T=313 C0.3. This model indicates that one factor (project scope factor) as measured by cost determines the duration of construction projects.

Similar studies were carried out by Ireland (1985) in Australia for building projects, Kaka and Price (1991) in the United Kingdom, Chan (1999) in Hong Kong using 110 building projects between 1980s and 1990s. In 2001, Chan further confirmed the BTC model by surveying 51 public projects in Malaysia. Hoffman *et al* (2007) collected for 856 construction projects completed between the period of 1988 to 2004 and validated Bromilow's model.

After the BTC model several studies have been undertaken to validate, improve or replicate the model for other categories of construction projects. Ireland (1986) replicated the study to predict construction time of high rise building in Australia. Kaka and Price (1991) examined the relationship of buildings and road projects in the United Kingdom. Kumaraswamy and Chan (1995) examined the time-cost relationship of buildings in Hong Kong. Chan (1999) conducted similar research of building projects in Malaysia. Ng *et al.* (2001) tested the BTC model and refitted it with a new set of data for Australian construction projects completed between 1991 and 1998. The result of the study indicated an improvement in construction speed over the period but the alteration made to the log-log model failed to produce any improved fit.

The BTC model was replicated by Choudhury and Rajan (2003) using 55 residential building project data in Texas. The result of the study indicated that the BTC model holds a good prediction for the Texas construction industry at the level of significance (p value) < 0.0001. All these studies revealed that the mathematical model presented by Bromilow *et al.* (1969) holds good for the prediction of construction time if the cost of construction is known. Ogunsemi and Jagboro (2006) developed a time-cost relationship of construction projects in Nigeria using 87 completed projects based on the concept of the BTC model. The result of the study produced a model T = 63C0.262 with a poor predictive ability for both private and public projects with R and R2 values of 0.453 and 0.205 respectively. In furtherance of this, they developed piecewise regression models for the prediction of the Time duration of construction projects.

Waziri (2012) developed a mathematical model in the form of BTC for the prediction of construction time using a data set of sixty completed institutional building projects in North Eastern Nigeria. The model showed a good fit to the data with R value of 0.845 and R2 value of

0.716. The model also showed a satisfactory prediction performance with mean absolute percentage error (MAPE) of 13.6% over a test sample.

Mak, Ng, Chen, and Varnam (2000) studied the predictive ability of the BTC model while investigating its relationship with "commonly used economic indicators in the construction industry" in Australia. The results show that, while the model provides a means of estimating and benchmarking project duration, the model needs to be regularly updated using current project data in order to ensure the BTCmodel is suitable as an industry standard. Recently, Mackova and Baskova (2014) applied the BTC model to 28 residential construction projects in Slovakia. These researchers derived the Bromilow constants and found that the BTC model is credible for residential constructions in Slovakia.

Ireland (1985) recognized the need to consider factors other than cost in predicting construction project duration for high-rise commercial buildings. He studied the effects of managerial actions on the project schedule. His study demonstrates clear links between managerial actions and achievement of project objectives related to cost, schedule, and quality for high-rise commercial building projects. However, the study confirms that the average construction time for high-rise commercial buildings is given by the BTC model with constants K = 219 and B = 0.47.

Bhoka and Ogunlana (1999) used the artificial neural network to predict the construction duration for buildings at the pre-design stage. One hundred and thirty six (136) building projects completed during the period 1987 – 1995 in Greater Bangkok were used for training and testing the network. The independent variables used as input variables were building height, functional area, structural system, foundation index, exterior finishes, quality of interior finishes and

accessibility to the site. The best network developed for the determination of construction duration at the pre-design stage had six hidden nodes with an average error of 13.6%.

Jin *et al.* (2016) developed a case-based reasoning model for multi-housing projects estimating the construction duration in the project planning phase and validated its applicability and effectiveness through application of 83 multi-housing projects. Czarnigowska and Sobotka (2013) applied the simple regression model to 100 road projects completed between the periods 2003 to 2008 in southwestern Poland to predict duration. Cost was the determining factor for the developed model expressed as Ln (L) = 1.206 + 0.4649 Ln C, where L is duration in days and C is the cost. The coefficient of determination (R2) was 0.6397 indicating that the model explains 64% of the variance in terms of cost.

Sobotka (2014) presented a model of the road construction duration based on relationships between the project qualities. These relationships were assumed to be determined while analysing project qualities likely to be known or estimated in the project planning phase. Kim *et al.* (2016) suggested a prediction model for dam construction duration based on activities that have a main effect on the overall dam construction duration. Because specific items (amount of rocks, pile depth, etc.) are established as influential factors, there is a limit in utilizing them during the project planning phase (Lee *et al.* 2010). General construction companies in Korea utilize their own construction duration computation models that are specialized for office buildings. On the other hand, they are also difficult to utilize during the project planning phase because they apply specific variables, such as the amount of soil excavated, rock composition ratio, number of tower cranes needed, etc. (Lee *et al.* 2010).

Martin *et al.* (2006) suggested a regression equation for computing the construction duration for various facilities including office buildings with the purpose of predicting the construction duration during the project planning phase. Lee *et al*. (2015) presented a regression model for the normal project duration based on the performance data of a water facility construction. Kim *et al*. (2016) derived a regression model for the duration of concrete-faced rock-fill dam construction in Korea based on performance data. Martin, Burrows, and Pegg (2006) verified that linear regression analysis can be used to estimate the construction duration for British factories, offices, hospitals, and schools in the project planning stage. Thus, various studies have developed regression models for construction project durations and obtained reliable results in terms of the error rate. Methods using regression models are reasonable in that they derive influence factors to estimate the project duration. These methods can be regarded as a useful tool for estimating the construction duration; however, they are not suitable for the renovation projects because these methods are deterministic, whereas renovation requires a stochastic approach.

A study was carried out by Ahmadu *et al.* (2015) who carried out a research for duration determination for building construction projects in Nigeria. Data for 96 completed building projects were obtained from construction firms in three major cities, Abuja, Kaduna and Kano through a self- administered questionnaire. Their questionnaire was designed to solicit information on both quantitative factors (cost, gross floor area and number of storeys) and qualitative factors affecting the duration of building projects. The qualitative factors determined to influence duration estimation included delay in progress payment by owner, lateness in revising and approving design document by owner, delay in delivering the site to the contractor by the owner and change order by owner during construction. Ahmadu *et al.* (2015) subjected

the collected quantitative and qualitative factors to a multivariate analysis and regression models were obtained for public, private and all projects with good predictive abilities.

Williams (2008) conducted a study to develop mathematical models for preliminary prediction of highway construction duration. The study identified the project factors which influence highway construction duration in the early stages and also quantified the relationship between the duration-influential factors and highway construction duration. The quantity, magnitude, and sign of the factor coefficient yields evidence regarding the importance of the project factor to highway construction duration. In summary, Williams (2008) incorporates the duration-influential project factors and their relationship with highway construction duration into mathematical models which assist in the prediction of construction duration. Full and condensed models are presented for Full- Depth Section and Highway Improvement project types. The author used statistical regression analysis to identify, quantify, and model these early-known, duration-influential project factors.

Abu Hammad *et al*. (2008) conducted a study to develop a prediction model for construction cost and duration in Jordan. Statistical regression models and sample tests are developed using real data of 140 projects. The prediction models were developed based on historic data of similar projects.

Al-Momani (2000) developed a quantitative regression model for estimating the actual time using the data of 130 public building projects constructed during 1990-1997 in Jordan. The study also identified the most critical factors affecting projects delays. He concluded that the main causes of delay in construction projects are caused by: designers, owner changes, weather,

differing site conditions, delay in material deliveries, economic conditions and increase in quantities.

Mahamid (2013) conducted a study aims at developing of regression models to predict the total cost of road construction project during the project early phases. 52 sets of data collected in Saudi Arabia were used to develop the models. Mahamid (2013) concluded 5 regression models; 2 of them include bid quantities of the major construction activities as independent variables and the other 3 include road length and road width as independent variables. Chan and Chan (2004) conducted a study in Hong Kong. They developed a benchmark model for project time performance in Hong Kong. In their study, they identified the critical factors influencing construction durations of high-rise public housing buildings in Hong Kong. Through their analysis, they determined five statistically significant regression variables: (1) total construction cost, (2) type of housing scheme, (3) use of pre-cast facades, (4) building volume, and (5) ground floor area per floor.

Love, Tse, and Edwards (2005) further studied the concept of GFA after concluding that cost is a poor predictor of project time since the real project cost cannot be known before completion of the project and proposed a model based on the GFA and the number of floors in a building. Their resulting model was shown to have greater predictive accuracy than the BTC model. Bayram (2016) investigated the validity of the BTC model and Love *et al*.'s GFA model using data from 530 public building projects in Turkey. Bayram's 2016 study concluded that, for the public building construction industry in Turkey, Bromilow's model provided more accurate predictions than Love *et al*.'s GFA model. However, the study also proposed a best-fit model based on the premise that building area and height are the main predictors of project duration (Bayram, 2016).

Thal, Webb, and Weir (2007) tested the BTC model using data from 580 US Air Force facility construction projects, developed a multiple linear regression (MLR) model based on these same 580 projects, and concluded that their MLR model performed better than the BTC model in predicting project duration. Guerrero *et al.* (2014) studied project duration in the construction industry in Spain and identified construction speed as a more appropriate response/dependent variable than construction time for modeling project duration of building construction in Spain.

In corroboration of the results obtained by Love *et al*. (2005), Chen and Huang (2006) determined a significant influence of the gross floor area on the duration of school reconstruction projects in Taiwan. On the other hand, based on data collected for 856 facility projects which were completed between 1988 and 2004, Hoffman *et al*. (2007), in an attempt to gain insight into the significant factors affecting construction duration in the U.S., analyzed the data using both the time-cost and multiple linear regression models. The outcomes suggested that, while a significant correlation was found to exist between cost and duration, the multiple linear regression model was found to provide the most acceptable prediction. Le-Hoai and Lee (2009) surveyed 34 historical building projects in Korea and determined weak predictive ability of Bromilow's time-cost model, and thus proposed alternative models to estimate building construction durations. Moreover, the data for 62 completed building projects that were carried out within the period 2000–2007 in Ghana were modeled by (Ameyaw *et al*., 2012). The results obtained revealed that the time-cost relationship is generally inapplicable to the Ghanaian building construction industry.

Nani *et al.* (2017) developed a model for forecasting duration for bridge projects. 100 questionnaires were distributed to construction professionals at the Department of Feeder Roads (rural road agency) to ascertain their views on the work items in a bill of quantities (BOQ) that impact significantly on the duration of bridge construction projects. Historical data for 30 completed bridge projects were also collected from the same Department. The data collected were executed work items in bills of quantities (BOQ) and actual durations used in completing the works. The qualitative data was analyzed using the relative importance index (RII) and the quantitative data, processed and analyzed using both the stepwise regression method and artificial neural network (ANN) techniques. The identified predictors, namely; in-situ concrete, weight of prefabricated steel components, gravel sub-base and haulage of aggregates used as independent variables resulted in the development of a regression model with a mean absolute percentage error (MAPE) of 25% and an ANN model with a feed forward back propagation algorithm with an MAPE of 26% at the validation stage. The study has shown that both regression and ANN models are appropriate for predicting the duration of a new bridge construction project.

Lee – Hoai *et al.* (2013) developed a time performance index using 70 building projects in Vietnam. They first used the stepwise regression method to identify significant predictors and developed both regression and ANN model for the Vietnamese construction industry. Hammad *et al.* (2010) used 113 building projects in Jordan to develop a probabilistic model for predicting the risk effects of time and cost for public buildings. Dursan and Stoy (2011) used 246 building projects in 25 different countries to test the statistical adequacy of categorizing projects with respect to their locations for construction modelling. Dursan and Stoy (2012) again developed regression models for building projects in Germany by analyzing 30 quantitative and 4

qualitative variables. Bhoka and Ogunlana (1999) used 136 building projects to develop an ANN model for duration determination in Greater Bangkok.

Kim *et al*, (2016) used the quantities of work items and the critical path method to model the duration for dam construction projects in Korea. Liu *et al*, (2012) conducted a study using 416 bridge construction projects from the North Carolina Department of Transportation (NCDOT). They analyzed the data by first identifying project factors that influenced the duration of bridge projects. Among the project factors that they investigated, four descriptive factors significantly influenced the preliminary engineering duration and these factors were the "geographical area of the state, classification of the required National Environmental Policy Act (NEPA) document, bridge construction scope, and responsible party preparing the NEPA document**.**" For validation purposes, the authors randomly used 60 of the 416 bridge projects before developing the regression model and validated the model achieving a mean absolute percentage error (MAPE) of 21% when applied to the validation set. Based on these results, they recommended that the NCDOT can use the regression equation to estimate the duration of bridge projects.

Irfan *et al*, (2011) also developed models for highway and bridge construction projects in the state of Indiana in the United States. The variables used in the developed models were the anticipated project cost and the contract type. They developed models using the log linear for logistic modelling and obtained the following models for five project types:

Y = e4.87+0.299*Cost+0.268*Contract type for road maintenance projects

Y = e4.60+0.34*Cost+0.253*Contract type for road resurfacing projects,

Y = e4.70+0.307*Cost+0.237*Contract type road construction projects,

Y = e4.57+0.34*Cost+0.409*Contract type for traffic projects

Y = e4.43+0.345*Cost+0.367*Contract type for bridge projects where Y is the duration in days. They indicated that the developed models can help project administrators provide improved estimates of project duration at the planning stage and thus reduce project time delays.

Jiang *et al*. (2010) also developed time -cost models for bridge replacement, bridge rehabilitation and highway projects for the Indiana Transportation Department in the United States. Cost was the independent variable used in their model.

Kim *et al*. (2019) developed a multiple linear regression model for mixed-use buildings, 1,969 mixed-use building project data were collected. The final prediction model for mixed-use buildings with five independent variables was suggested in the study. Its R2 was 0.637 and Ra2 was 0.635. In addition, the results of the validation showed that the prediction model's average prediction accuracy, MAPE, and RMSE were 88.51%, 75.94, and 11.49% respectively. Given that the prediction model is applied in the project planning phase when there is insufficient information on the project, the results are believed to be at a considerably reliable level.

Jarkas (2015) examined the validity and applicability, of the time-cost model to estimate contract durations for building construction in the State of Kuwait, and proposed an alternative model, taking into consideration other potentially influential project scope variables on time performance. Relevant data for 113 residential and 74 office buildings, which were completed during the period 2004–2010, were collected by a questionnaire survey and subsequently analyzed using both the time-cost model and a multiple linear regression model comprising the project construction area as well as the number of floors above and below ground. While the results obtained further affirm the predictive ability of Bromilow's time-cost model, a comparison between the outcomes of both models tested demonstrates that, on average, the

multifactor model proposed is associated with an enhanced prediction accuracy of 16 and 14% for residential and office buildings, respectively, and therefore can be deemed more suitable for forecasting local construction duration for the building types investigated. Innocent *et al*. (2018) uses data from 466 MILCON projects to identify key factors that influence project duration and provide a new model to predict project time outcomes. The model generates accurate results and serves as a useful tool in the early phases of a project life cycle.

Yoon and Yu (2017) developed a model for apartment remodeling, same authors developed a new model in 2019 for apartment remodeling considering extension type renovation. Factors needed for the development of constructability model for building renovation were discovered by Yoon *et al.* (2019) also, a model was developed for predicting the duration of sustainable apartment renovation. Experts were asked to estimate a baseline schedule for extension-type renovation projects, factors that influence critical path activities, and the range of project durations considering these factors. An equation for estimating the duration of a renovation project was developed, and the range of project durations was derived using a MCS to reflect uncertainty. The proposed model was validated by applying it to actual cases. The case study shows that the model would be more suitable for complex renovation construction (i.e., more than two buildings or vertical extension). The model can be applied to various renovation projects and used as a reference for determining contract time.

2.4 The Criticism of the Models

Regression Models are related with mathematical values and very sensitive to data distribution. Therefore, if the variables are not clear, it is not possible to use regression models. (Sezgin, 2003) Time-cost models and parametric models had close reasonably accurate estimations. The

predictive accuracy of time-cost models was slightly better than parametric models. However, parametric estimations do not require cost estimation. (Helvacı, 2008) In the study carried out by Helvacı (2008), ANN and regression analysis‟ predictive accuracies had no significant differences. Linear regression analyses were considered to provide an adequate and pragmatic methodology for conceptual duration estimation of construction projects.

The main advantage of the neural network models is their capability to capture the non-linear relations as well as linear relations. (Helvacı, 2008) However, as Helvacı (2008) points out, an increase in the number of variables increases the complexity of the model. The construction industry is very complex, which contains hundreds of activities. (Bhokha and Ogunlana, 1999) Hence, Artificial Neural Network Models require trained professionals to estimate the construction duration.

Fuzzy Logic Models based on the conversion of linguistic expressions (like very god, good, fairly good) to mathematical values are appropriate for construction industry as compared with Regression Models and ANN‟s. Experience and institutions gain importance. However, if the people taking decisions are not efficient enough, it may lead to wrong decisions.(Sezgin, 2003).

2.5 Artificial Neural Network

2.5.1 General Overview

Artificial neural network (ANN) model is model which makes use of processing units which are connected by links with the processing unit grouped into three main layers, namely input layer, hidden layer and output layers (Afrifa *et al.*, 2012). An artificial neural network (ANN) is an intelligent system which is based on biological neural networks (Singh and Chauhan 2009; Jha

and Chockalingam 2011; Petruseva *et al.*, 2013). It consists of many interconnected but artificial neurons which weighs, sums and threshold incoming signals to produce an output (Taylor *et al*, 2007). The development of neural networks was motivated by the desire to both understand and emulate how the brain functions. Often just referred to as Neural Networks (NN), with artificial implied, NN importantly retains two important features of the biological neural network, i.e. the ability to learn from experience Hinton (1992) and make generalisations based on this acquired knowledge (Haykin, 1994). The ANN does not make prior assumptions about the distribution of the data or the form of interactions between factors (Singh and Chauhan, 2009). ANN is robust, has the ability to adapt to unknown datasets and has a good learning capability (Jha and Chockalingam, 2011).

2.5.2 Artificial Neural Network Structure

The ANN makes use of processing units which are connected by links with the processing unit grouped into three main layers named; input layer, hidden layer and output layers (Afrifa *et al* 2012). The input layer receives information from the outside world (which in this case is the significant quantities obtained from the regression analysis) with the hidden layer serving the purpose of creating an internal representation of the problem. The output layer gives solution to the problem by offering a more accurate prediction which is duration in this research. This type of network is called the multi–layer perceptron (MLP).

Neural network's computations happen within the hidden layer, which also becomes the permanent memory of the model after training for predicting new cases. The predictive performance of the neural network can be increased by increasing the number of hidden layers or nodes in the hidden layer, although this must be kept as low as possible to ensure the network does not just *memorise* the data instead of *learning* the underlying patterns and correlations

within it. Memorising in model development is called overfitting (Haykin 1994). An overfitted model generally tends to perform very well during training, but performance drastically deteriorates when new data is presented to the network to validate it.

The output layer receives and stores or transfer processed data from the network (Fausett 1994). The output of the neural network is a function of the weighted sum of all neurons in the network, a completely deterministic result.

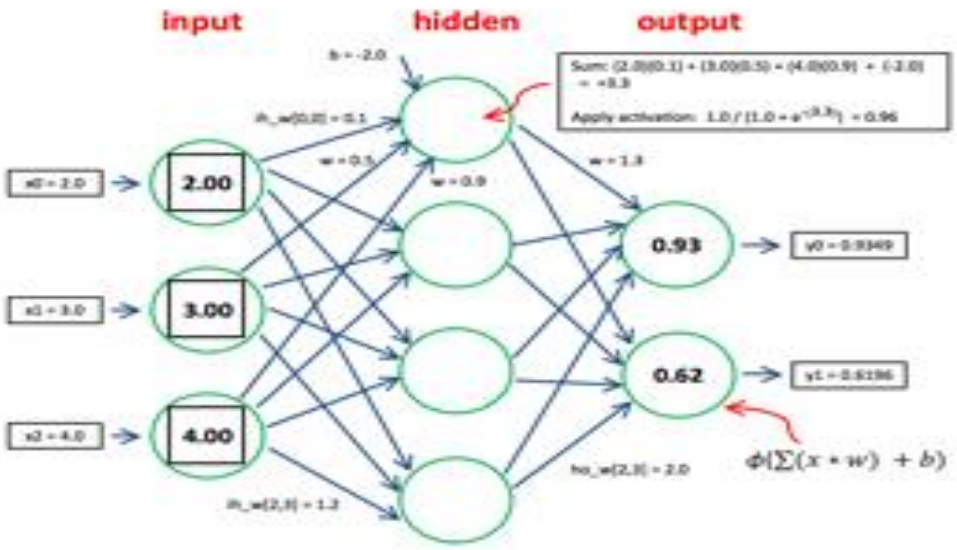


Figure 1: Sample of ANN Architecture (adapted from McCaffrey, 2013)

2.5.3 Types of Neural Network Architecture

The Multilayer Perceptron (MLP) and the Radial Basis Function (RBF) are the two network architectures available in feed forward neural network. According to Santos *et al.* (2013), the RBF and MLP networks are usually applied to the same kind of problem domains, i.e. approximation and pattern recognition. They mainly differ only in their internal calculation structures. RBFs are linear while MLPs are nonlinear functions. Also, while RBF maps the

relationship between input and target in a 2 phases, first performing a probability distribution of the inputs before the searching for relationships between the input and output space in the next stage, MLPs on the other hand go through just the second stage of the RBF (StatSoft Inc. 2011b).

2.5.4 Applications of Artificial Neural Network

Neural networks are the preferred tool for many predictive applications because of their power, flexibility, and ease of use (IBM, 2012). Predictive neural networks are particularly useful in applications where the underlying process is complex, such as:

i. Forecasting consumer demand to streamline production and delivery costs.
ii. Predicting the probability of response to direct mail marketing to determine which households on a mailing list should be sent an offer.
iii. Scoring an applicant to determine the risk of extending credit to the applicant.
iv. Detecting fraudulent transactions in an insurance claims database.

2.5.5 Artificial Neural Network in Construction

In the field of construction, Sonmez and Rowings (1998) developed neural network models for quantitative evaluation of labour productivity for concrete pouring, formwork, and concrete finishing tasks, using data compiled from eight building projects. Al-Tabtabai and Alex (1999) present a neural network approach to estimating the preliminary cost of highway projects using 9 project factors including type of road, soil nature, location and hauling distance. They first used

case-based reasoning to collect relevant project factors on 40 different projects before modelling these factors using ANN. They reported a mean square error of 9% when the models were validated with new data. In a similar research, Wilmot and Mei (2005) present a neural network approach that estimates the escalation of highway construction costs over time. The model relates overall highway construction costs to the cost of construction material, labour and equipment as well as the characteristics of the contract and the contracting environment prevailing at the time the contract was let.

CHAPTER THREE

Research Methodology

3.1 Approaches to Research

According to Rahman (2017), qualitative and quantitative research approaches are frequently used in research across several fields. Qualitative research is an inductive approach to knowledge building, which involves exploring, investigating the phenomenon, in order to understand people's perspective of the phenomena (Leavy, 2017). Furthermore, qualitative research retains the natural setting with the inclusion of the complexities of the environment (O'Dwyer & Bernauer, 2014).

Quantitative research involves a deductive approach to knowledge seeking, which seeks to obtain knowledge through simplifying the complexity settings of the natural environment (O'Dwyer & Bernauer, 2014). In addition, quantitative research aims to prove, disprove existing theories (Leavy, 2017). Quantitative research involves data that can be quantified.

Mixed research method is the type of research which combines elements of qualitative and quantitative research, such as data collection techniques, analysis e.t.c with the aim of having a broader and deeper understanding (Schoonenboom & Johnson, 2017). According to Johnson, *et*

al. (2007), mixed methods research can either be qualitative dominant, quantitative dominant or at the centre of the continuum.

For the purpose of this study, Quantitative research approach was adopted. A field survey was carried out with the objective of obtaining and gathering information in respect to the subject matter. Quantitative research approach has the capacity of enabling the classification and counting of features, as well as construction of statistical models to explain what is been observed (Babbie, 2010).

3.2 Data Collection

Methods of collecting data shapes the analysis which may be carried out, including the results, conclusions, values and validity of the study (Fellows and Liu, 1997). For a quantitative research approach, the methods commonly used to obtain numeric/quantitative data include; surveys, experiments/testing, use of pre-existing/secondary data as well as systematic observation. The data used for this research work was collected via a questionnaire survey.

3.2.1 The Questionnaire Survey

In a bid to get a reasonably high response for a questionnaire survey, self-administration of the questionnaires or postal survey is recommended (Fellows and Liu, 1997). Both methods for the administration of questionnaires are effective provided the addresses of the respondents are available and accessible to the researcher. Both the self-administered survey and postal survey using Email were adopted for this study.

3.2.2 Structure of the Questionnaire

For the purpose of this study, a questionnaire survey was used to get information on Tertiary Education Trust Fund (TETFund) renovation projects completed between the years 2015-2020 which was taken as the survey population of the study.

The questionnaire was divided into three parts. The first part obtained information about the person filling the questionnaire which provided the basis to ascertain the accuracy of information provided. The second part consisted question about scope factors influencing duration of building renovation works, the respondents were asked to give the information specific to one project. The third part consisted the qualitative factors that affect duration of renovation projects, the respondents were asked to give their perception of how each factor affects' duration of the particular building renovation project in question on a five point likert type scale with 1 meaning very low, 2 meaning low, 3 meaning moderate, 4 meaning high and 5 meaning very high.

3.3 **Population**

The perspective of a research indicates the population of concern (Fellows and Liu, 1997). For the purpose of this study, looking into the objectives which the questionnaire survey intends to achieve, building renovation projects clearly represented the context of the research and hence, the population of concern. Owing to the finding that poor classification of projects is responsible for unsuccessful results of some previous models by Kaka and Price (1993), TETfund building renovation projects executed within 2015-2020 were taken as the study population. Since the total number of TETFund building renovation projects completed between the years 2015-2020 (as shown on TETFund's website) approximated to 357, the survey population of the study was set at 357.

3.4 Sample Size

The sample of a study is not the same as the population under investigation in situations where members of the population under investigation are common, it is therefore necessary to scientifically find a sample of the population to be included in the survey without biasing the study's findings (Mathers, Fox and Hunn, 2009). In order to determine this sample, the Krejcie and Morgan (1970)'s formula was adopted. Krejicie and Morgan (1970) formula computes sample size as:

$$S = \frac{Z^2 NP(1-P)}{d^2(N-1) + X^2 P(1-P)} \quad \text{..... Equation (1)}$$

Where;

S = required sample size

X2 = table of value of chi-square for 1 degree of freedom at the desired confidence level (3.841)

N = the population size

P = the population proportion (assumed to be 0.50)

d = degree of accuracy expressed as a proportion (0.05)

Substituting for survey population (N) in the formula in equation (1) gave the sample size as 186. However, because Salkind (1997) has recommended that "when mailing out surveys or questionnaires, count on increasing the sample by 40%-50% to account for lost mail and uncooperative subjects", a total of 260 (186 plus 40% of 260) questionnaires were issued out to survey respondents, instead of 186 computed as the sample size.

3.5 Sampling Technique

This study adopted a purposive sampling technique. As identified by Babbie (2013), purposive sampling is adopted where the study area of a researcher possesses a certain cultural background having professionals with in-depth knowledge. As a result, the informants for this study were carefully chosen using the condition that only professionals who have executed renovation projects funded by Tetfund. This was done to guarantee that only professionals with sound experience and knowledge of duration of building renovation projects funded by Tetfund participated in the survey.

3.6 Assesment of Qualitative Factors

The qualitative factors that affect duration of building renovation projects were assessed using descriptive statistics (using SPSS 25), the mean score of each factor was calculated and factors were ranked in ascending order.

3.7 Model Development

Some of the available techniques for model development include but not limited to case-based reasoning, regression, principal component analysis, neural networks, decision trees, fuzzy logic and genetic algorithm. The main issues to consider are usually around the aim of the modelling exercise, the predictive performance required or the type of data available. Each technique can also be assessed in terms of its features. For example, concerning 'interpretability', while regression models generate an equation whose physical properties can be easily interpreted in terms of the variables used, neural networks on the other hand, do not produce any equation (Ahiaga-Dagbui, 2014).

Sarle (1994) neural networks have been derided by Sarle (1994) as 'black-boxes'. When prediction is intended, Artificial Neural Network (ANN), also called Neural Networks, is the appropriate tool (Odeyinka, 2003; Odeyinka *et al.*, 2013; McCaffrey, 2013). Neural networks are the preferred tool for many predictive applications because of their power, flexibility, and ease of use (IBM, 2012). For the sake of this study Artificial Nueral networks was used for model development.

3.7.1 Training

Similar to the brain, NN learn by examples. Learning in ANN terminology has been defined by Haykin (1994) as "a process by which the free parameters of a neural network are adapted through a continuing process of stimulating by the environment in which the network is embedded." Training the neural network is thus a process of iteratively adjusting the network weights and threshold until it is able to learn, i.e. approximate the underlying functional relationship between inputs and target(s). The learning period of a ANN is bounded by rules that govern how weights adapt in response to a learning example, how many times the learning process is carried out, etc. A training dataset, consisting of input-target pairs are presented one after another to the network during training for learning. It might be easier to view training as a question and answer session, with inputs as 'questions' and targets as 'answers'. During learning, the network is effectively being asked questions (inputs). Given the current question, the network

error is measured by comparing the answer produced by the network (output) with the actual expected answer (target). Should the performance not be satisfactory, the network weights are adjusted to produce a more correct answer on another attempt, a process called back-propagation in ANN terminology (Fausett, 1994). All models in this study were developed following the the trial and error method adopted in literature.

3.8 Model Validation

Model was validated by comparing the model's prediction and actual duration of projects that were kept aside for data validation. 10% of the data was used for validation alone. The Mean Absolute Percentage Error (MAPE) of the selected model will be used to verify predictions by comparing model predictions and estimator's original prediction also T-test was used to validate the models by comparing the means of actual duration and that of models prediction

CHAPTER FOUR

Data Analysis

4.1 Introduction

This chapter comprises the presentation and interpretation of data obtained from the questionnaire survey. The finding in respect to the aim and objectives of this research will be discussed and deductions will be made scientifically to help arrive at valuable conclusions and recommendations.

4.2 Retrieved Data from Questionnaire Survey

Out of a total of 260 questionnaire issued out in during the course of data collection, a total of 121 were retrieved and useable which is 46.54% of distributed questionnaire as shown in Table 4.1.

To determine the reliability of data, cronbach's alpha was test was conducted due to the fact that the study questionnaire has a multiple likert scale section. The cronbach"s alpa test score was 0.967 which is very close to one, these proves that there exist an excellent measure of concept in the multiple likert scales section of the questionnaire and the data is adequate for analysis. The result of the cronbach's alpha test is shown in Table 4.2

Table 4.1: Breakdown of Questionnaire

Questionnaire	**Number**	**Percentage**
Retrieved	121	46.54
non-retrieved	139	53.46
Total	260	100.00

Table 4.2: cronbach's Alpha

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	Number
0.967	0.967	47

4.3 Survey Respondents

For the purpose of this research, construction companies were selected to be the respondents on the perception that they have more and accurate information regarding the performance of any building project. It is however very important that only staff with accurate knowledge of projects in the organization fill the questionnaire on behalf of the construction company. Section A of the

questionnaire provides room for the respondent to state his management rank/level and years of experience in the organisation. Table 4.3 and 4.4 shows the result respectively.

Table 4.3: Rank of respondents in organisation

level in organization	Frequency	Percentage
Top Level	41	33.88
Middle Level	59	48.76
Low Level	21	17.36
Total	121	100.00

As shown in the table 4.3, 33.9% of the respondents belong to the top level management, 48.8% belong to the middle level management, 17.4% belongs to the low level management and 0% belongs to the operational level. From we can deduct that 82.7% of the questionnaires were filled by people with in-depth knowledge of project while 17.4% was filled by people with average knowledge of projects. No single respondent was from the operational management level. This indicates that the data obtained can be considered reliable and accurate.

Table 4.4: Experience of Respondents

Years In Service	Frequency	Percentage
1-5 years	34	28.10
6-10 years	41	33.88
11-15 years	30	24.79
16-20 years	14	11.57
20 and above	2	1.65
Total	121	100.00

Table 4.4 above shows that 1.65% of the respondents has 20 years and above of experience in their respective organisation, 11.57% have 16-20 years, interestingly 24.79% have 11-15 years of

service, and a large percentage of the respondents which is 33.88% have 6-10 years of experience and lastly 28.1% of respondents has 1-5 years if experience.

From the above we can see that 71.9% of the respondents have 6years and above experience and only 38.1% of the respondents have more than 10 years of experience.

4.4 Survey Population

Due to the nature of this research, building renovation projects executed using the traditional procurement route were selected. Details of various categories of projects and profession of the respondents will be provided in Tables 4.5 and 4.6

Table 4.5: Categories of TETFund Renovation Projects Surveyed

Project type	Frequency	Percentage
Block of offices and lecture halls	77	63.64
Library	25	20.66
Lecture Theatre	19	15.70
Total	121	100.00

As we can see from Table 4.5, block of office and lecture hall, library, hostel and lecture theatres are the categories of building renovation projects from the retrieved questionnaires. Block of offices and lecture Halls carries the largest percentage with 63.64%, it is followed by Library which has a percentage of 20.66%, lecture theatre is the third with a population percentage of 15.70%. This shows that more attention is given to the renovation of block of offices and lecture halls and least attention is given to hostel renovation.

Table 4.6: Profession of Respondents

Profession	**Frequency**	**Percentage**

quantity surveyor	46	38.02
Architect	40	33.06
Builder	23	19.01
Project Manager	12	9.92
Total	121	100.00

Table 4.6 shows that 38% of the respondents are quantity surveyors, 33% are Architects, 19% are Builders and 9.9% are Project Managers. This shows that majority of the respondents are Quantity Surveyors.

4.5 Predictor Variables.

For the purpose of this research, the variables that affect duration we categorized into two for effective data collection and analysis. The two categories are scope (quantitative) factors and non-scope (qualitative).

Table 4.7: Information relating to scope factors that affect duration

Scope Factor	**Mean**	**Standard deviation**
Final Cost	31700000	4023000
Height	5.75	0.282
Gross Floor Area	528.4	44.57
Number of Storey	0.61	0.64

4.6 Ranking Of Non-Scope Based Factors That Influence Duration

Non-scope (Qualitative) factors which affect duration of construction works identified by previous researchers in literature were carefully articulated and arranged into a list of 47 factors

in accordance to mean score of the rating of the extent to which each factor influence duration of building renovation works by the respondents.

Table 4.8: Information relating to Qualitative factors considered in this study that affect duration

FACTOR	MEAN	RANK
Variations	4.01	1
Incomplete scope of work	3.86	2
Material delivery	3.84	3
Scarcity of material	3.71	4
Labour Productivity	3.69	5
Owner financial capacity	3.66	6
Change in currency rate	3.65	7
Onsite access	3.59	8
Work hour restriction	3.49	9
Fluctuation	3.48	10
Team experience	3.46	11
Planning and scheduling	3.44	12
Inflation	3.40	13
Rework	3.36	14
Design error	3.31	15
Labour skill level	3.21	16
Delay in inspection and Testing	3.19	17
Experience of contractor	3.18	18
Progressive payment	3.16	19
Communication	3.14	20
Government policies	3.11	21
Delay in obtaining permit	3.09	22
Nominated supplier	3.07	23
Change in laws and regulations	3.04	24
Complexity of design	3.03	25
Postponement of project	3.01	26
Human resource planning	2.75	27
Late site handover	2.69	28
Rate of interest	2.58	29
Delay in approval	2.55	30
Weather	2.43	31
Equipment breakdown	2.42	32
Labour accident	2.4	33
Site congestion	2.37	34
Material storage	2.35	35
Delay in subcontractor work	2.35	35
Safety regulation	2.35	35
No of subcontractors	2.33	38

FACTOR	MEAN	RANK
Bribery and corruption	2.27	39
Differing site condition	2.19	40
Equipment maintenance	2.16	41
Site location	2.11	42
Subsurface condition	2.05	43
Security	1.93	44
Frequent change of contractor	1.89	45
Wars and conflict	1.60	46
Natural disaster	1.45	47

Table 4.8 shows rank of factors which affects duration of building renovation works, the rank is based on mean score of the ranks (extent to which each factor affects construction time) given on a 5 point Likert scale by the respondents.

The table shows that variations with a mean score of 4.01 is ranked first. This shows that building renovations works are characterized with so much variations. This is due to the fact that owners change specification as work progress and also because some items to be renovated are only discovered as work commences.

The factor ranked second is incomplete scope of work 3.86. Earlier in this study it was stated that Saleh (2009) revealed that renovations are characterized with inaccurate scope of works. This further proves the aforementioned assertion, the quantity of work to be done is directly proportional to amount of time take to finish so if the quantity of work to be done is incomplete obviously the estimated duration will not be sufficient for the work.

The factor ranked third is material delivery with a mean score of 3.84. Without materials construction works cannot proceed. Any lacuna associated with delivery of materials to site will

seriously affect construction duration and may likely result to duration overrun. This is in-line with findings of Alwi & Hampson (2003) and Alaghbari *et al.* (2007) and clearly contradicts the findings of Al-khalil *et al.* (1999) Chan & Chan (2002) and Assaf & El-hejji (2006).

The fourth factor according to the table is scarcity of materials having a mean score of 3.71. when materials are not available definitely work will stop until they become available The research results of Ogunlana *et al*. (1996), Abudul-Rahman *et al*. (2008), Sambasivan and Soon (2007), and Alaghbari *et al*. (2007) concur with this result, that the shortage of construction materials at site is a very important cause of delay. This result reflects the importance of materials in the construction process. The results of Mezher *et al*. (1998), Alwi and Hampson (2003), Odeh & Battaineh (2002), Assaf & El-hejji (2006), and Fong *et al*. (2006) contradict this result. The countries/ locations surveyed by these researchers involve international open markets, such as Thailand, which implies that construction materials should be readily available.

The fifth factor is labour productivity with a mean score of 3.57. The higher the productivity the faster the project moves likewise the lower the productivity the slower the project. A glitch in labour productivity obviously impact the duration of building renovation works this further buttresses the findings of (Kaming *et al*. 1997).

The other factors that make up the top ten factors that influence duration of renovation works are owner financial capacity, change in currency rate, onsite access, work hour restriction and lastly fluctuation. These factors are ranked in the other in which they were listed.

The table also shows that 17 factors have a mean score of less than 2.5 which is 50% of the maximum rank (5) on the likert scale. Such factors can be said to have less impact on duration of

building renovation works. The factors are weather, equipment breakdown, labour accident, site congestion, material storage, delay in subcontractor's work, safety regulation, substructure condition, bribery and corruption, differing site condition, equipment maintenance, site location, number of subcontractors, security, frequent change of contractor wars and conflict and natural disaster. The factors are ranked from 31-47 respectively

The poor mean scores of differing site conditions and subsurface conditions shows that most renovation works are not associated with ground works and these makes it entirely different from new construction. The findings of this study contradicts the findings of Enhassi *et al.* (2010) and Chan & Chan (2002) and thus buttress the fact that renovation works are quite different from new construction.

Table 4.9: Analysis of variance of influence of qualitative factors on duration across project categories

Dependent variable	**Sig**
Bribery and corruption	0.965
Owner financial capacity	0.872
Site congestion	0.741
Security	0.508
Communication	0.476
Delay in approval	0.415
Team experience	0.345
Government policies	0.342
Labour accident	0.330
Inflation	0.328
Material delivery	0.319
Frequent change of contractor	0.300
Subsurface condition	0.293
Complexity of design	0.257
Experience of contractor	0.257
Delay in inspection and Testing	0.254

Dependent variable	Sig
Labour skill level	0.229
Change in currency rate	0.225
Wars and conflict	0.175
Change in laws and regulations	0.174
Material storage	0.164
Labour Productivity	0.164
No of subcontractors	0.158
Rework	0.140
Natural disaster	0.130
Design error	0.110
Equipment breakdown	0.065
Human resource planning	0.062
Postponement of project	0.053
Progressive payment	0.049
Delay in subcontractor work	0.045
Nominated supplier	0.040
Site location	0.018
Fluctuation	0.016
Safety regulation	0.015
Delay in obtaining permit	0.014
Weather	0.010
Equipment maintenance	0.009
Scarcity of material	0.006
Onsite access	0.003
Variations	0.003
Differing site condition	0.003
Incomplete scope of work	0.002
Work hour restriction	0.002
Rate of interest	0.001
Planning and scheduling	0.001
Late site handover	0.000

From table 4.9, we can see that there was statistically significant difference in the way the following factors namely progressive payment, delay in subcontractor work, nominated supplier, site location, fluctuation, safety regulation, delay in obtaining permit, weather, equipment maintenance, scarcity of materials, onsite access, variation, differing site condition, incomplete

scope of work, work hour restriction, rate of interest, planning and scheduling and late site handover weather, affect the duration of various types of building renovation projects because they have a sig value that is less than 0.05.

4.7 Developing The Nueral Network Model.

The Artificial Nueral Network was developed using IBM-SPSS 21. The type of neural network model developed for this study is multilayer perceptron also called feed forward model the decision to select this method was informed by the fact that similar studies conducted by Mensah(2016) and Nani *et al* (2017) used the method to predict duration of bridge and road construction respectively.

4.7.1 Variables Classification

The variables were classified into three types namely nominal, ordinal and scale. The scale variables are for this research includes final cost, building height, number of storeys, and gross floor area. The model has only one nominal variable which is project type and lastly the model has 47 factors which are ordinal variables. These variables are listed in table.

The data were further divided into dependent and predictor variables. The predictor variables are further divided into covariates and factors. The scale variables are classified as covariates while nominal and ordinal variables are classified as factors.

4.7.2 Cases Partitioning

The dataset used to develop the model was divide into training, testing, and holdout samples. Random partitioning of the neural networks in the SPSS software was selected. The training

sample comprises the data records used to train the neural network; 80% assigned to the training sample in order to obtain a model. The testing sample is an independent set of data records used to track errors during training in order to prevent overtraining.

It is highly recommended that you create a training sample, and network training will generally be most efficient if the testing sample is smaller than the training sample hence, 10% of the data was used as testing data. The holdout sample is another independent set of data records used to assess the final neural network; the error for the holdout sample gives an "honest" estimate of the predictive ability of the model because the holdout cases were not used to build the model 10% of data was allocated to the hold out sample. The relative number (ratio) of cases randomly assigned to each sample (training, testing, and holdout) are 80:10:10 respectively.

4.7.3 Model Structure (Architecture)

The artificial neural network structure is made up of the input layer, hidden layer and output layer. The Architecture tab is used to specify the structure of the network. The procedure can select the

"best" architecture automatically, hence it was used for this study. Automatic architecture selection builds a network with one hidden layer. Automatic architecture selection uses the default activation functions for the hidden and output layers.

4.7.4 Training

The training method adopted for this model is batch training, batch method**.** Updates the synaptic weights only after passing all training data records; that is, batch training uses information from all records in the training dataset. Batch training is often preferred because it directly minimizes the total error; however, batch training may need to update the weights many times until one of

the stopping rules is met and hence may need many data passes. It is most useful for "smaller" datasets.

Table 4.10: Predictor variables of the Artificial Neural Network Models

PREDICTOR VARIABLES MULTI-LAYER PERCEPTRON MODEL		PREDICTOR VARIABLES RADIAL BASIS FUNCTION MODEL	
S/NO	INPUT VARIABLES	S/NO	INPUT VARIABLES
1	Variations	1	Variations
2	Incomplete scope of work	2	Incomplete scope of work
3	Material delivery	3	Material delivery
4	Scarcity of material	4	Scarcity of material
5	Labour Productivity	5	Labour Productivity
6	Owner financial capacity	6	Owner financial capacity
7	Change in currency rate	7	Change in currency rate
8	Onsite access	8	Onsite access
9	Work hour restriction	9	Work hour restriction
10	Fluctuation	10	Fluctuation
11	Team experience	11	Team experience
12	Planning and scheduling	12	Planning and scheduling
13	Project type	13	Inflation
14	Cost	14	Project type
15	Gross floor area	15	Cost
16	Height	16	Gross floor area
17	Number of Storey	17	Height
		18	Number of Storey

Table 4.11: Models Summary

	NO OF VARIABLES IN INPUT LAYER	NUMBER OF UNITS IN INPUT LAYER	TRAINING RELATIVE ERROR	TESTINGRELATIVE ERROR	NO OF UNITS IN HIDDEN LAYER	HIDDEN LAYER ACTIVATION FUCTION	OUTPUT LAYER ACTIVATION FUNCTION
GENERAL MODEL							
MLP	17	55	0.452	0.198	2	HYPERBOLIC TANGENT	IDENTITY
RBF	18	59	0.591	0.224	2	SOFTMAX	IDENTITY
BLOCK OF OFFICES AND CLASSROOMS							
MLP	17	51	0.361	0.12	8	HYPERBOLIC TANGENT	IDENTITY
RBF	18	54	0.388	0.174	9	SOFTMAX	IDENTITY
LECTURE THEATRES							
MLP	17	41	0.24	0.06	6	HYPERBOLIC TANGENT	IDENTITY
RBF	18	44	0.32	0.11	7	SOFTMAX	IDENTITY
LIBRARIES							
MLP	17	44	0.28	0.09	9	HYPERBOLIC TANGENT	IDENTITY
RBF	18	46	0.328	0.13	2	SOFTMAX	IDENTITY

The table above gives general information about the network it shows that the multi-layer perceptron model retained 17 variables as predictors out of which 13 are scope based factors and 4 are non-scope based factors, this shows that all 4 non scope based factors have high impact on duration while the Radial basis function model retained 18 variables as predictors out of which

13 are scope based factors and 4 are non-scope based factors, this shows that all 4 non scope based factors.

Table 4.11 shows that 8 models were developed, two models to predict duration of general renovation works and 6 models to predict duration of each category of renovation work, this became necessary due to the fact that statistical significance in duration was discovered among different categories of renovation works. For each category, two models were developed namely the radial basis function model and the multi-layer perceptron model.

4.7.4.1 MLP Model General.

- The model contains 17 significant factors which are recognized by the neural network as predictor variables, they comprise 12 non-scope factors and 5 scope factors
- The hidden layer contains 2 unobservable nodes. The value of each hidden unit is some function of the predictors generated by the network. The hidden nodes determine the relationship between the inputs and the outputs in what is termed a “black box” manner. This means that Apart from defining the general architecture of a network and perhaps initially seeding it with a random numbers, the user has no other role than to feed it input and watch it train and await the output. 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.
- The output layer contain one node which is Actual duration

- The relative error of the model during training was 0.452 and 0.198 during testing testing, this shows that the developed model has a final performance of 80.2 % during model development.

4.7.4.2 RBF Model General.

- The model contains 18 significant factors which are recognized by the neural network as predictor variables, they comprise 13 non-scope factors and 5 scope factors
- The hidden layer contains 2 unobservable nodes. The value of each hidden unit is some function of the predictors generated by the network. The hidden nodes determine the relationship between the inputs and the outputs in what is termed a “black box” manner. This means that Apart from defining the general architecture of a network and perhaps initially seeding it with a random numbers, the user has no other role than to feed it input and watch it train and await the output. 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.
- The output layer contain one node which is Actual duration
- The relative error of the model during training was 0.591 and 0.224 during testing, this shows that the developed model has a final performance of 78.6 % during model development.

4.7.4.3 MLP Model Block Of Offices And Classrooms.

- The model contains 17 significant factors which are recognized by the neural network as predictor variables, they comprise 12 non-scope factors and 5 scope factors

- The hidden layer contains 8 unobservable nodes. The value of each hidden unit is some function of the predictors generated by the network. The hidden nodes determine the relationship between the inputs and the outputs in what is termed a “black box” manner. This means that Apart from defining the general architecture of a network and perhaps initially seeding it with a random numbers, the user has no other role than to feed it input and watch it train and await the output. 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.
- The output layer contain one node which is Actual duration
- The relative error of the model during training was 0.361 and 0.12 during testing, this shows that the developed model has a final performance of 88% during model development.

4.7.4.4 RBF Model Block of Offices and Classrooms

- The model contains 18 significant factors which are recognized by the neural network as predictor variables, they comprise 13 non-scope factors and 5 scope factors
- The hidden layer contains 9 unobservable nodes. The value of each hidden unit is some function of the predictors generated by the network. The hidden nodes determine the relationship between the inputs and the outputs in what is termed a “black box” manner. This means that Apart from defining the general architecture of a network and perhaps initially seeding it with a random numbers, the user has no other role than to feed it input and watch it train and await the output. 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.

- The output layer contain one node which is Actual duration
- The relative error of the model during training was 0.388 and 0.174 during testing, this shows that the developed model has a final performance of 82.6% during model development

4.7.4.5 MLP Model Lecture Theatres.

- The model contains 17 significant factors which are recognized by the neural network as predictor variables, they comprise 12 non-scope factors and 5 scope factors
- The hidden layer contains 6 unobservable nodes. The value of each hidden unit is some function of the predictors generated by the network. The hidden nodes determine the relationship between the inputs and the outputs in what is termed a “black box” manner. This means that Apart from defining the general architecture of a network and perhaps initially seeding it with a random numbers, the user has no other role than to feed it input and watch it train and await the output. 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.
- The output layer contain one node which is Actual duration
- The relative error of the model during training was 0.240 and 0.060 during testing, this shows that the developed model has a final performance of 94% during model development.

4.7.4.6 RBF Model Lecture Theatres.

- The model contains 18 significant factors which are recognized by the neural network as predictor variables, they comprise 13 non-scope factors and 5 scope factors
- The hidden layer contains 7 unobservable nodes. The value of each hidden unit is some function of the predictors generated by the network. The hidden nodes determine the relationship between the inputs and the outputs in what is termed a “black box” manner. This means that Apart from defining the general architecture of a network and perhaps initially seeding it with a random numbers, the user has no other role than to feed it input and watch it train and await the output. 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.
- The output layer contain one node which is Actual duration
- The relative error of the model during training was 0.320 and 0.11 during testing, this shows that the developed model has a final performance of 89% during model development.

4.7.4.7 MLP Model Library.

- The model contains 17 significant factors which are recognized by the neural network as predictor variables, they comprise 12 non-scope factors and 5 scope factors

- The hidden layer contains 9 unobservable nodes. The value of each hidden unit is some function of the predictors generated by the network. The hidden nodes determine the relationship between the inputs and the outputs in what is termed a “black box” manner. This means that Apart from defining the general architecture of a network and perhaps initially seeding it with a random numbers, the user has no other role than to feed it input and watch it train and await the output. 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.
- The output layer contain one node which is Actual duration
- The relative error of the model during training was 0.28 and 0.09 during testing, this shows that the developed model has a final performance of 91% during model development.

4.7.4.8 RBF Model Library.

- The model contains 18 significant factors which are recognized by the neural network as predictor variables, they comprise 13 non-scope factors and 5 scope factors
- The hidden layer contains 2 unobservable nodes. The value of each hidden unit is some function of the predictors generated by the network. The hidden nodes determine the relationship between the inputs and the outputs in what is termed a “black box” manner. This means that Apart from defining the general architecture of a network and perhaps initially seeding it with a random numbers, the user has no other role than to feed it input and watch it train and await the output. 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.

- The output layer contain one node which is Actual duration
- The relative error of the model during training was 0.328 and 0.13 during testing, this shows that the developed model has a final performance of 87% during model development.

4.7.5 Summary.

The finding above shows that the multilayer perceptron models developed for each category performed better than the radial basis function models, this goes hand in hand with the findings of Ahiaga-dagbui (2014). The results also revealed that models developed for different categories of renovation works have superior performance than the general model, this further validates the assertion that poor classification is the reason for failure of models (Kaka and Price 1993)

4.8 Model Validation

Making use of data not used in the model development process which is clearly defined as the holdout sample 16 cases (10% data set aside from the study's data), during the automatic partitioning of data process. The model (developed algorithm) was tested by comparing its predictions with the actual duration estimates. This is done in other to ascertain the level of accuracy achieved by incorporating both scope and non-scope factors in modelling duration of renovation works

Table 4.12: Mean absolute percentage error for general model

Actual Duration(in weeks)	MLP Model's estimate(in weeks)	RBF Model's estimate(in weeks)	MLP Percentage error	MLP Mean absolute Percentage error	RBF Percentage error	RBF Mean absolute Percentage error
36	33	29	0.083	0.08	0.194	0.194
34	30	31	0.118	0.12	0.088	0.088
21	24	28	-0.143	0.14	-0.333	0.333
19	17	22	0.105	0.11	-0.158	0.158
12	14	11	-0.167	0.17	0.083	0.083
14	11	13	0.214	0.21	0.071	0.071
37	42	48	-0.135	0.14	-0.297	0.297
8	7	5	0.125	0.13	0.375	0.375
16	18	22	-0.125	0.13	-0.375	0.375
14	11	13	0.214	0.21	0.071	0.071
22	19	25	0.136	0.14	-0.136	0.136
19	21	23	-0.105	0.11	-0.211	0.211
			MAPE	**0.14**	MAPE	**0.20**

Table 4:13 T test for general model.

	Mean	standard deviation	standard eror	Sig
Actual duration	21	9.68	2.796	0.643

MLP Model prediction	20.58	10.21	2.948	
Actual duration	21	9.68	2.796	0.328
BRF Model prediction	22.5	11.36	3.281	

Table 4.14: Mean absolute percentage error for block of office and classrooms models

Actual Duration(in weeks)	MLP Model's estimate(in weeks)	RBF Model's estimate(in weeks)	MLP Percentage error	MLP Mean absolute Percentage error	RBF Percentage error	RBF Mean absolute Percentage error
34	32	30	0.059	0.059	0.118	0.118
21	18	23	0.143	0.143	-0.095	0.095
19	16	22	0.158	0.158	-0.158	0.158
14	15	12	-0.071	0.071	0.143	0.143
16	14	13	0.125	0.125	0.188	0.188
21	19	19	0.095	0.095	0.095	0.095
18	19	22	-0.056	0.056	-0.222	0.222
22	24	21	-0.091	0.091	0.045	0.045
			MAPE	**0.1**	MAPE	**0.13**

Table 4.15: T test for block of offices and classrooms models

	mean	standard deviation	standard eror	Sig
Actual duration	20.62	6.04	2.14	0.200
MLP Model prediction	19.64	5.87	2.08	

Actual duration	20.62	6.04	2.13	0.732
BRF Model prediction	20.25	5.75	2.03	

Table 4.16: Mean absolute percentage error for library models

Actual Duration(in weeks)	MLP Model's estimate(in weeks)	RBF Model's estimate(in weeks)	MLP Percentage error	MLP Mean absolute Percentage error	RBF Percentage error	RBF Mean absolute Percentage error
40	38	44	0.050	0.050	-0.100	0.100
23	26	25	0.130	0.130	-0.087	0.087
26	28	21	-0.077	0.077	0.192	0.192
			MAPE	**0.09**	MAPE	**0.13**

Table 4.17: T test for library models

	mean	standard deviation	standard eror	sig
Actual duration	29.66	9.07	5.24	0.58
MLP Model prediction	30.67	6.43	3.71	
Actual duration	29.66	9.07	5.24	0.914
BRF Model prediction	30	12.28	7.09	

Table 4.18: Mean absolute percentage error for lecture theatre models

Actual Duration(in weeks)	MLP Model's estimate(in weeks)	RBF Model's estimate(in weeks)	MLP Percentage error	MLP Mean absolute Percentage error	RBF Percentage error	RBF Mean absolute Percentage error
64	64	65	0.000	0.000	-0.016	0.016
32	31	34	0.031	0.031	-0.063	0.063
			MAPE	**0.02**	MAPE	**0.04**

Table 4.19: T test for lecture theatre models.

	mean	standard deviation	standard eror	Sig
Actual duration	48	22.62	16	0.501
MLP Model prediction	47.5	23.34	16.5	
Actual duration	48	22.62	16	0.205
BRF Model prediction	49.5	21.92	15.5	

The tables above show the accuracy of the model at validation stage, t-test and mean absolute percentage error were usesd. The p values of all 8 models developed are as follows 0.643, 0.328, 0.200, 0.732, 0.580, 0.914, 0..501, 0.205 in the following other; MLP(General), RBF(General), MLP(Block of offices and classroom), RBF(Block of offices and classrooms), MLP(Library), RBF(Library), MLP(Theatre), RBF(Theatre), The p values aforementioned shows that no significant difference exist between the models prediction and actual duration this corroborates with the relatively low mean absolute percentage errors of the models which are as follows in the same other; 0.14%, 20%, 10%, 0.13%, 9%, 13% 2% and 4%.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Summary of Findings

The findings of the study after data analysis and discussion of result are:

a) Variations, incomplete scope of work, material delivery, scarcity of material and labour productivity have high impact on duration of renovation works.

b) Frequent change of contractor, wars and conflict and Natural disaster are the last three factors that have impact on duration of building renovation projects.

c) Scope factors namely cost, gross floor area building height, building height, type of building, and number of storey are important in predicting durations of building renovation works as they were all retained by the models.

d) The accuracy of the models increases when building renovation projects were classified according to type of building.

e) The multilayer perceptron models have higher accuracy than the radial basis function models.

5.2 Conclusion

The study concludes that the model which incorporate both scope and non-scope factors is a good predictor of duration of renovation works due to the following Mean absolute Percentage errors 0.14%, 20%, 10%, 0.13%, 9%, 13% 2% and 4%. The following MAPEs correlate with the following t-test results 0.643, 0.328, 0.200, 0.732, 0.580, 0.914, 0..501, 0.205 which also show that no significant difference exist in the models prediction and actual durations of the projects. The better the classification the higher the accuracy of model as the MAPE decreased when classification was improved.

5.3 Recommendations

a) Contractors should be wary of the effect of qualitative factors when estimating duration of building renovation projects

b) Contractors should take into consideration the factors that have varying effect according to type of building renovation project.

c) Studies should be conducted to develop models that incorporate uncertainty factors into predictions of duration.

d) Model for predicting duration of renovation projects of other infrastructure projects like roads, bridges, dams etc. should be developed.

e) A software/application/user interface/web-based platform should be developed for full and easy implementation of the Neural Network models developed.

5.4 Contribution to Knowledge.

a) The study provides literature with an assessment of factors that influence duration of renovation projects, The study discovered that variation, incomplete scope of work and material delivery are the most influential factors with mean scores of 4.01, 3.86, 3.84 respectively while frequent change of contractors, wars and conflict and natural disaster are the least influential with mean scores of 1.89, 1.6 and 1.45 respectively.

b) The study developed artificial neural network models which incorporates both scope and non-scope factors in predicting duration of building renovation projects, the 8 models developed in the study have a mean absolute percentage errors of 14%, 20%, 10%, 0.13%, 9%, 13% 2% and 4%The study provides literature with an assessment of factors that influence duration of renovation projects.

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APPENDECES

Questionnaire



DEPARTMEMNT QUANTITY SURVERYING OF
FACULTY OF ENVIRONMENTAL DESIGN
AHMADU BELLO UNIVERSITY
ZARIA KADUNA STATE.
QUESTIONNAIRE

Request for assistance in data collection for research project

Dear respondent,

I am Haruna Lawal Saidu, an Msc 2 Project Management Student from Ahmadu Bello University, Zaria. I kindly request your assistance in filling the questionnaire before you as a means of gathering information for the research project "MODELLING DURATION OF BUILDING RENOVATION PROJECTS" which is mandatory for the award of M. Sc. Degree in Project Management. Response to the following questions is required based on your personal experience and knowledge. All information /data provided in this questionnaire will be strictly treated as confidential and no part whatsoever will be used for any other purpose apart from this research.

Your valuable contributions towards the success of this work will be highly appreciated.

Thank you.

Yours faithfully,

Haruna Lawal Saidu

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NB: EACH QUESTIONNAIRE CARRIES INFORMATION FOR A SINGLE PROJECT.

Section A

Please underline the right option

1) Please which of the following best describes your rank in the company?

   (A) Top Level Management (B) Middle Level Management (C) Low Level Management (D) Operational Level Management

2) Please which of the options is your profession?

   (A) Architect (B) Builder (C) Civil Engineer (D) Quantity Surveyor (E) Project Manager

3) Kindly select the option that best describes your years of experience in handling building renovation works.

   (A) 1-5 years (B) 6-10 years (C) 11-15years (D)16-20 years (E)21 and above

Section B

This section contains list of some factors that influence the duration of buildings renovation works. You are required to use any TETFUND building renovation project of your choice, executed within the period of 2015-2020 in any Nigerian state via the traditional procurement method to provide the information below.

i. Initial Contract Sum:_____

ii. Actual Contract Sum:_____

iii. Initialy Estimated Duration:_____

iv. Actual Duration:_____

v. Building height: :_____

vi. Gross Floor Area:_____

vii. Number of Storeys:_____

viii. Project type (house, office, shops, school, hospital, theatres, etc):_____

Section C

This section contains list of non-scope factors (qualitative factors) that affect duration of building renovation. You are required to give your assessment of the extent to which each factor affect initial duration of renovation works to give rise to the final duration on the 5-point Likert scale comprising 1-very low, 2-low, 3-moderate, 4-high and 5-very high.

S/N	ATTRIBUTES		1	2	3	4	5
1.	Natural disaster						
2.	Weather condition						
3.	Subsurface condition						
4.	Site location						
5.	Onsite congestion						
6.	Security requirements						
7.	Safety regulations						
8.	Differing site condition						

9.	Labour skills level						
10.	Labour productivity on site						
11.	Labour accidents						
12.	Human resource planning						
13.	Working hours restriction						
14.	Equipment breakdown						
15.	Equipment maintenance						
16.	Material delivery						
17.	Material storage						
18.	Incomplete scope of work						
19.	Nominated suppliers						
20.	Onsite access						
21.	Team experience						
22.	Design error						
23.	Number of subcontractors						
24.	Late site hand over						
25.	Variations						
26.	Postponement of project						
27.	Fluctuation						
28.	Change in currency rate						

29.	Owner financial capacity						
30.	Progressive payment						
31.	Rate of interest						
32.	Bribery and corruption						
33.	Wars and conflict						
34.	Changes in laws and regulation						
35.	Communications						
36.	Planning and scheduling of project						
37.	Inflation						
38.	Government policies						
39.	Experience of the contractor						
40.	Delay in performing inspection and testing						
41.	Complexity of design						
42.	Scarcity of materials						
43.	Delay in approval						
44.	Delay in sub-contractor works						
45.	Delay in obtaining permits						
46.	Frequent change of subcontractor						
47.	Rework						

Network architecture for general model

Network architecture for block of classrooms and offices model

Network architecture for library model

Network architecture for lecture theatre model