ANALYSIS OF UNIT RATES FOR ROADWORKS IN ZAMBIA INCORPORATING NEURAL NETWORK PREDICTION AND FIRST PRINCIPLES ESTIMATING

By

BALIMU MWIYA

A thesis submitted to the University of Zambia in fulfilment of the requirements for the Degree of Doctor of Philosophy in Construction Management

The University of Zambia

Lusaka

2016

COPYRIGHT DECLARATION

I, **Balimu Mwiya**, do declare that this thesis is entirely my own except as specified in acknowledgements and that neither the thesis nor the original work contained therein has been submitted to this or any other institution for a higher degree. Publications from this work are attached as Appendix L.

Signed:…………………………………

Date:……………………………………

Lusaka, Zambia

CERTIFICATE OF APPROVAL

This thesis of **Balimu Mwiya** is approved as fulfilling the requirements for the award of the Degree of **Doctor of Philosophy** in **Construction Management** at the University of Zambia

NAME	**SIGNATURE**
Prof. Mundia Muya	
Supervisor	
Prof. P.D. Rwelamila	
External Examiner	
Dr. Ian N. Banda	
Internal Examiner	
Dr E. Mwanaumo	
Internal Examiner	

ABSTRACT

Road transport is an important sector of economic activity, especially in developing countries, where it plays an essential role in marketing agricultural products and providing access to health, education and agricultural inputs and extension services. Zambia as a land locked country has been working hard to become “land linked”. The country has the potential of attracting more transit traffic and becoming a regional distribution centre for all kinds of goods and commodities. The Zambian road network is one of the country’s largest public sector assets. It is therefore essential that this vital asset is managed efficiently and effectively, invariably within a constrained budgetary situation, in support of socio-economic growth and the development of the country. It is perceived by stakeholders that Zambia does not always get value for money in road infrastructure delivery. Industry regulators and public institutions have indicated that there was a notable trend in varying costs of construction from project to project and from one public institution to another, that it had become increasingly difficult to ascertain the true cost of projects and thereby unable to guarantee value for money.

The research aimed at developing a unit cost estimation model (UCEM) for roadworks incorporating neural network (NN) to provide a standardised procedure of pricing road activities in Zambia and help understand prevailing market rates in the Zambian road sector (ZRS). The research involved establishing the base rates and determining the economic strata to form the unit rates used in the model. The base rates of the 854 pay items from the Southern Africa Transport and Communications Commission (SATCC) Standard Specifications for Road and Bridge Works used in the ZRS were calculated from first principles. The economic strata involved establishing the cost factors that affect construction unit rates (CUR) in the ZRS. From reviewed literature, forty five (45) cost factors were identified. Expert opinion reduced the factors to thirty one (31). The expert opinion was obtained through the Delphi technique and Pareto analysis was used to further analyse the factors and reduce them to twenty five (25). Further information on the 25 factors was obtained through questionnaire survey. Using factor analysis the 25 factors were further reduced to eight (8). The established 8 factors namely: contractor capacity; project location; period of honouring payments; level of design; cost escalation; materials availability; country corruption profile; and political environment were identified as those that impact unit costs in the ZRS. The 8 factors were then analysed using NN to determine the proportionate breakdown of the cost factors in a given unit rate. The UCEM incorporated quantitative base unit rates and quantified qualitative economic strata to establish the prevailing rate. The UCEM was validated using real system measurements from three (3) SADC countries and five (5) local road projects.

The value of the study is to provide a standardised procedure of pricing road activities to ensure uniformity in public and private procurement practice in the ZRS. The UCEM would assist those involved with roads project estimating to calculate the Engineers' estimate with a fairly high level of accuracy. Finally, it is hoped that the model would provide a generic acceptable rate analysis system that can be used as a basis to compare against future projects.

Key words: construction unit rates, neural networks, cost factors, unit cost estimation model, Zambian road sector.

DEDICATION

To Alexius Nyambe Mwiya

MYSRIP - You were part of this dream.

To Emily Mwanza Mwiya

For showing me the strength of a woman.

To Mwiinga & Maloko

Eat your hearts out!

ACKNOWLEDGEMENTS

Sincere gratitude to my supervisor and mentor Prof. Mundia Muya, firstly, for believing in me and for the continuous support, patience and motivation of my PhD study.

I am especially indebted to the Unit Cost study team - M. Muya, C. Kaliba, E. Nkole, G. Limunga and M. Mwenda

Special thanks to participants of expert interview for without them this study would not have been completed. Mr. Clifford Mwanang'ombi and Mr. Tadg Wixted thank you for your special contribution.

Many thanks to the University of Zambia in particular colleagues in the Dept. of Civil & Environmental Engineering for the encouragement and support during the course of this study.

I will forever be indebted to my sisters Nalishebo, Mwangala and Tasila Mwiya *(you started the journey with me)* for being my backbone and walking with me. Heartfelt gratitude to my family - Nancy, Wabei, Meya, Mwiinga, Chimuka, Maloko, Luziya, Richie, Alex, Philomena and Marian.

Father Inyambo Lubinda, who taught me that when life gets too hard to stand, KNEEL.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF EQUATIONS

LIST OF ABBREVIATIONS

AACE	Association for the Advancement of Cost Engineering
ABCEC	Association of Building & Civil Engineering Contractors
ACEZ	Association of Consulting Engineers of Zambia
ASG	Association of General Contractors of America
AU	African Union
BEE	Black Economic Empowerment
BoQ	Bill of Quantities
BP	Back propagation
BVS	Best Value Selection
C#	C Sharp
CER	Cost Estimating Relationship
CIDB	Construction Industry Development Board
CLP	Construction Labour Productivity
COMESA	Common Market for Eastern and Southern Africa
CPI	Consumer Price Index
CPI[1]	Corruption Perception Index
CPs	Cooperating Partners
CRN	Core Road Network
CUR	Construction Unit Rate
DANIDA	Danish International Development Agency
DOT	Department of Transport
GDP	Gross Domestic Product
GMDH	Group Method of Data Handling Networks
GRNN	General Regression Neural Network
GRZ	Government of the Republic of Zambia
GUI	Graphical User Interface
HCPI	Harmonised Consumer Price Indices
JICA	Japan International Cooperation Agency
LRA	Local Road Authorities
MAL	Ministry of Agriculture and Livestock
MDB	Multilateral Development Banks

MLGH	Ministry of Local Government and Housing
MTA	Ministry of Tourism and Arts
MTWSC	Ministry of Transport, Works, Supply and Communication
NCC	National Council for Construction
NFRA	National Road Fund Agency
NN	Neural Networks
NUBEGW	National Union of Building, Engineering & General Workers
P&G	Preliminary and General
PNN	Probabilistic Neural Network
PSI	Project Specific Indicator
RDA	Road Development Agency
RMI	Road Management Initiative
RoadSIP	Road Sector Investment Programme
RSAWP	Road Sector Annual Work Plan
RTSA	Road Transport & Safety Agency
SADC	Southern African Development Community
SAFCEC	South African Federation of Civil Engineering Contractors
SANRAL	South African National Roads Agency Limited
SATCC	Southern Africa Transport and Communications Commission
SNDP	Sixth National Development Plan
SPSS	Statistical Package for Social Sciences
SQL	Structured Query Language
TANROADS	Tanzania Road Authority
TIZ	Transparency International Zambia
UCEM	Unit Cost Estimation Model
ULM	UCEM labour method
UNZA	University of Zambia
US$	United States Dollar
USA	United States of America
VAT	Value Added Tax
VfM	Value for Money
WB	World Bank
WBS	Work Breakdown Structure
ZCI	Zambian Construction Industry

ZMW	Zambian Kwacha (rebased)
ZPPA	Zambia Public Procurement Authority
ZRS	Zambian Road Sector

Chapter One: Introduction

1.1 Background

Road infrastructure provides a fundamental foundation to the performance of national economies, delivering a wide range of economic and social benefits. As a landlocked country, the Zambian road network is one of the country's largest public sector assets. The Government of the Republic of Zambia (GRZ), through the Road Development Agency (RDA) embarked on a Road Sector Investment Programme (RoadSIP II). The focus of RoadSIP II was to bring the Core Road Network (CRN) into serviceable and maintainable standards to facilitate connectivity, poverty alleviation, agricultural and marketing activities. GRZ's proactive initiatives were aimed at transforming Zambia into a truly *land linked country* in the Southern Africa sub-region. Road infrastructure requires appropriate funding and good management to ensure maximum value is achieved. Inadequate levels of investment or poor management of the road network have serious consequences for economies and social well-being of citizens.

The major source of funding for infrastructure development in developing countries has been Multilateral Development Banks (MDB). Without support from MDB or Cooperating Partners (CPs), projects in poorer, unstable or high-risk developing countries would often not go ahead. World Bank-financed projects result in 40,000 contracts being awarded annually and account for one third of total international contracts in developing countries (Hawley, 2004).

Zambia, like any other developing country, has experienced increased activity in construction works especially in the road sector in the past few decades. The RDA indicates that the budget for the 2009 Road Sector Annual Work Plan (RSAWP) was ZMW1.356 trillion equivalent to US$ 270 million. Compared to 2008, the total budget to the Road Sector increased by 12 percent (RDA, 2010). The 2009 RSAWP comprised 22 percent funding from GRZ, 31 percent from the Road Fund and the remaining 47 percent from CPs as shown in Figure 1.1. CPs committed in excess of US$130 million to the road sector alone in 2009 (RDA, 2010).

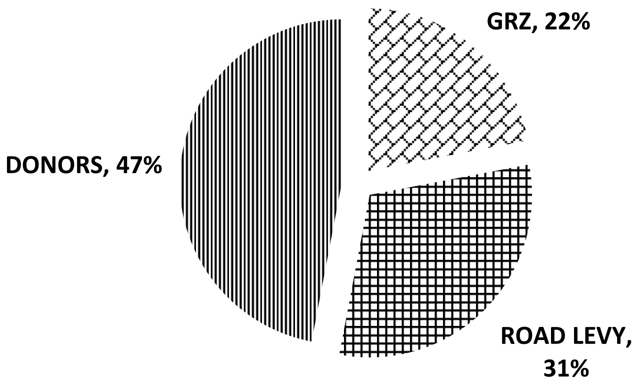


Figure 1.1: RSAWP 2009 funding source
(After Road Development Agency, 2010)

Given their major role in financing and facilitating funding for infrastructure projects in low income countries such as Zambia, MDBs and CPs have a critical role to play in ensuring value for money. The concept of value for money (VfM) is key in the use of public funds. In Zambia, public procurement is estimated at 10 percent of gross domestic product (GDP), and is therefore one of the top three types of spending besides salaries and debt re-payments (Kaela, 2004). The citizens require assurance that public infrastructure is being purchased at the correct price, and not necessarily the lowest. The question is what is the correct price for one (1) km of a road? The prominence of VfM in the development agenda is that there is no fixed price of public infrastructure delivery. Two exact roads built in the same geographical location will never have the same price. In addition, the price of a road varies depending on the distance from the project start point or chainage 0.0 + 0 km. However, assessing VfM is not a simple task in a developing country like Zambia because of limited standards, non-adherence to regulations and non-availability of reliable statistics. This is compounded by multiple stakeholders and their perspective of value for money. Project cost estimation does not necessarily provide the price but sets a baseline or history of looking at cost efficiency, effectiveness and economic variables. The National Audit Office (NAO) in the United Kingdom uses four criteria in assessing VfM of government spending (NAO, 2014):

a) economy (spending less);
b) efficiency (spending well);
c) effectiveness (spending wisely);
d) equity (spending fairly).

From the four criteria, this research intended to ensure that the Zambian road sector achieves VfM through efficient spending. While significant steps have taken place in recent years in ensuring VfM, serious vulnerabilities remain. Interest has therefore, grown in the investigation of Construction Unit Rates (CURs) particularly for paved roads. Improvements in data availability and mathematical techniques for studying the cost behaviour of firms allow for more in-depth study of the production technology employed in paved road construction.

The development of cost functions with more theoretically and mathematical methods makes development of CURs more scientific and objective. The reasons for studying such cost functions are many. Among them are regulatory and pricing requirements, labour and management perspectives, and investment decisions about the optimal mix of inputs to employ in the production process.

Road construction requires large amounts of capital investment and is thus a natural monopoly in the hands of the state as the employer. Following the widespread registration of foreign owned construction companies in the National Council for Construction (NCC) Grade 1 to 3 to carry out large road construction projects, there was renewed interest in the public sector and regulatory bodies in issues of appropriate pricing policies and industry structure. Consequently, there was need to establish the key factors that integrate into the ever increasing construction unit costs for roads in Zambia and compare these with those within the Southern African Development Community (SADC) region. To achieve this, the construction unit rate for roadworks was analysed using a cost structure which was the distribution of costs among the elements of the process. Costs in this instance refer not only to particular financial costs, but the use of resources generally.

Project managers consider cost estimating an art (Vojinovic et al., 2000). The accuracy of cost estimates is so important that a contingency for errors is incorporated in the estimate. However, Flyvbjerg (2006) stated that forecasts of cost, demand and other impacts of planned projects have remained consistently and remarkably inaccurate for decades. He further stated that inaccurate cost forecasts were a major source of risk to project management. Therefore accurate cost estimation has the potential to reduce project risk. Road construction is normally considered a long term project. Without accurate data, it is a daunting task to predict the future cost of goods and services. Inaccurate determination of cost escalation could result in non-viability of a project. Therefore, cost estimating is seen as one of the critical project success factors. It forms the basis for further planning and decision-making. By integrating cost estimation and cost control, the consequence of a failed or cancelled project is reduced. The guide on better cost predictability in construction emphasises that current and accurate information should be shared between stakeholders. The analysis of rates is a critical part of the project development process and when incorporated with quantities, provides the engineers estimate. The engineers estimate is important as it:

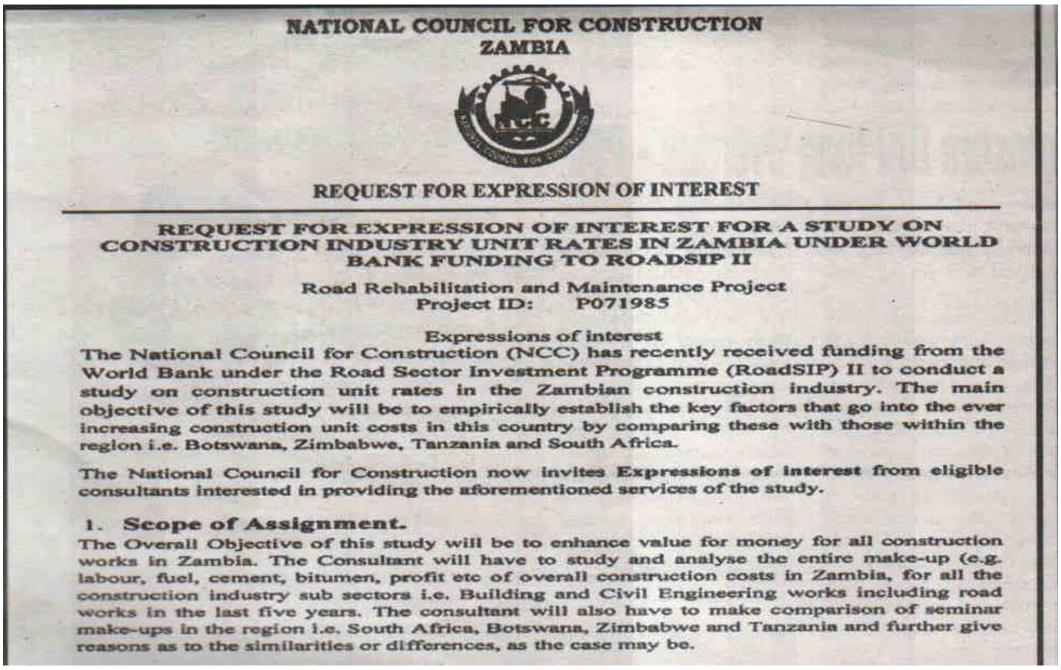
a) serves as a basis for probable construction cost;
b) supports decision-making on project scope; and
c) serves as a guide to evaluate bidders' proposals.

The Unit Cost Estimation Model (UCEM) has attempted to provide current and accurate information regarding unit rates. Akintoye (2000) attributed insufficient time to prepare an estimate to inaccurate cost prediction. This may be so, but it is doubtful whether cost estimate accuracy would improve with longer estimating durations. Parkinson's Law states that work expands to fill the time available to complete it (Parkinson, 1962). Therefore, what is significant is the availability of reliable data at the estimator's fingertips. Information such as productivity and materials waste data used to prepare estimates should be readily available. Formal sources of cost data could be established by encouraging the use of UCEM among stakeholders. This would lead to efficiency in the Zambian road sector (ZRS).

Accurate estimation of construction costs is heavily dependent on the availability of quality historical cost data and the level of professional expertise within the Zambian road sector (ZRS). The Association for the Advancement of Cost Engineering (AACE) defines cost engineering as the area of engineering practice where engineering judgment and experience are used in the application of scientific principles and techniques to the problems of cost estimation, control and profitability. Therefore, estimation is a prediction of the quantity of resources needed to accomplish an activity or create an asset. The two most common types of estimates are definitive and order of magnitude estimates. This study focused on developing a unit cost estimation model to derive definitive rates for the Zambian road sector by integrating mathematical equations with neural network cost estimating relationships.

1.2 Statement of the problem

It is perceived by stakeholders that Zambia does not always get value for money in infrastructure delivery. Major stakeholders such as the NCC, RDA and the Zambia Public Procurement Authority (ZPPA), have in the recent past called for an informed position on prevailing market rates in the Zambian construction industry. For instance, in March 2010 NCC ran an advertisement in the local media inviting Expressions of Interest (EOI) from consultants to carry out a study on CUR in Zambia under World Bank funding to RoadSIP II as depicted in Figure 1.2. The advertisement highlighted the need of a standardised way of arriving at a unit rate to enhance VfM. NCC (2010) stated that it was understandable for rates to rise as certain costs such as fuels and other inputs that go into construction works rise, however the rise in the costs had been too drastic for the Zambian industry.



NATIONAL COUNCIL FOR CONSTRUCTION
ZAMBIA

REQUEST FOR EXPRESSION OF INTEREST

REQUEST FOR EXPRESSION OF INTEREST FOR A STUDY ON CONSTRUCTION INDUSTRY UNIT RATES IN ZAMBIA UNDER WORLD BANK FUNDING TO ROADSIP II

Road Rehabilitation and Maintenance Project
Project ID: P071985

Expressions of interest

The National Council for Construction (NCC) has recently received funding from the World Bank under the Road Sector Investment Programme (RoadSIP) II to conduct a study on construction unit rates in the Zambian construction industry. The main objective of this study will be to empirically establish the key factors that go into the ever increasing construction unit costs in this country by comparing these with those within the region i.e. Botswana, Zimbabwe, Tanzania and South Africa.

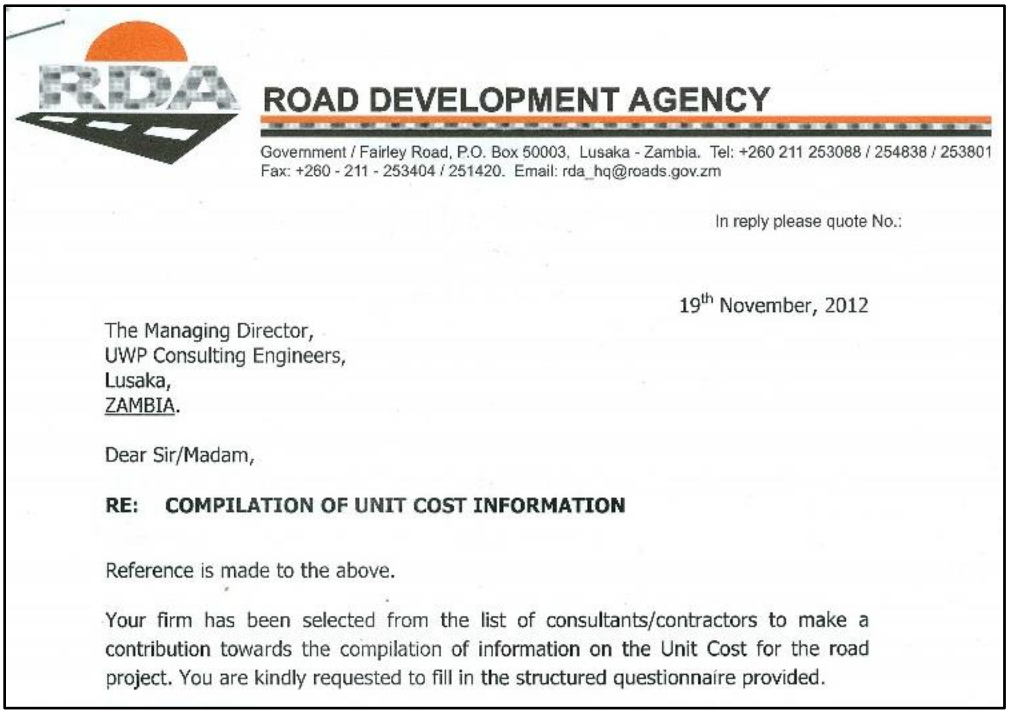
The National Council for Construction now invites Expressions of interest from eligible consultants interested in providing the aforementioned services of the study.

1. Scope of Assignment.

The Overall Objective of this study will be to enhance value for money for all construction works in Zambia. The Consultant will have to study and analyse the entire make-up (e.g. labour, fuel, cement, bitumen, profit etc of overall construction costs in Zambia, for all the construction industry sub sectors i.e. Building and Civil Engineering works including road works in the last five years. The consultant will also have to make comparison of seminar make-ups in the region i.e. South Africa, Botswana, Zimbabwe and Tanzania and further give reasons as to the similarities or differences, as the case may be.

Figure 1.2: Advertisement for NCC CUR study
(After Times of Zambia, 2010)

Later, in November 2012, the RDA requested information for compilation of unit cost for road works. The request letter shown in Figure 1.3 illustrates that the RDA sought information regarding CUR for road projects.


ROAD DEVELOPMENT AGENCY

Government / Fairley Road, P.O. Box 50003, Lusaka - Zambia. Tel: +260 211 253088 / 254838 / 253801
Fax: +260 - 211 - 253404 / 251420. Email: rda_hq@roads.gov.zm

In reply please quote No.:

19th November, 2012

The Managing Director,
UWP Consulting Engineers,
Lusaka,
ZAMBIA.

Dear Sir/Madam,

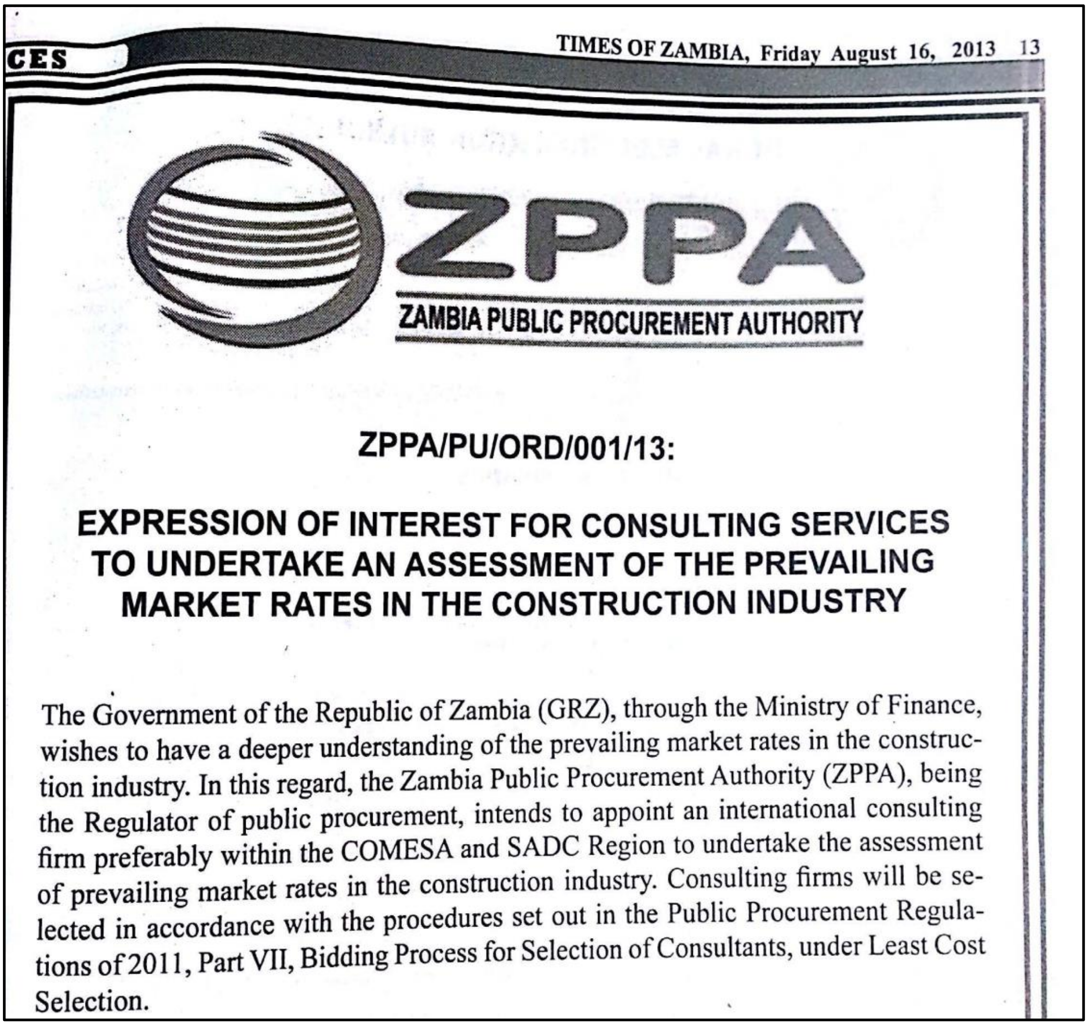
RE: COMPILATION OF UNIT COST INFORMATION

Reference is made to the above.

Your firm has been selected from the list of consultants/contractors to make a contribution towards the compilation of information on the Unit Cost for the road project. You are kindly requested to fill in the structured questionnaire provided.

Figure 1.3: Request letter for RDA CUR study
(After Road Development Agency, 2012)

Further, in August 2013, ZPPA ran an advertisement inviting EOI from consultants to provide guidance on the factors that influence the determination of rates in the construction industry. The EOI depicted in Figure 1.4 clearly expressed that there were no guidelines or standards regarding CUR in the Zambian Construction Industry (ZCI). ZPPA (2014) stated that there was a notable trend in varying costs of construction from project to project and from one public institution to another, that it had become increasingly difficult to ascertain the true cost of projects and thereby unable to guarantee value for money.



CES — TIMES OF ZAMBIA, Friday August 16, 2013 13

ZPPA

ZAMBIA PUBLIC PROCUREMENT AUTHORITY

ZPPA/PU/ORD/001/13:

EXPRESSION OF INTEREST FOR CONSULTING SERVICES TO UNDERTAKE AN ASSESSMENT OF THE PREVAILING MARKET RATES IN THE CONSTRUCTION INDUSTRY

The Government of the Republic of Zambia (GRZ), through the Ministry of Finance, wishes to have a deeper understanding of the prevailing market rates in the construction industry. In this regard, the Zambia Public Procurement Authority (ZPPA), being the Regulator of public procurement, intends to appoint an international consulting firm preferably within the COMESA and SADC Region to undertake the assessment of prevailing market rates in the construction industry. Consulting firms will be selected in accordance with the procedures set out in the Public Procurement Regulations of 2011, Part VII, Bidding Process for Selection of Consultants, under Least Cost Selection.

Figure 1.4: Advertisement for ZPPA CUR study
(After Times of Zambia, 2013)

Varying approaches to cost estimating between contractors, consultants and client organisations result in inconsistencies. Therefore, stakeholders have requested guidance on what constitutes construction unit rates in Zambia as there is no basis of the estimate reflected in a documented or accepted industry standard. Because of this Zambia, does not have a cost estimate classification system which would provide guidelines for applying general principles of estimate classification to assess project cost estimates.

The consequences of an ill-defined cost estimation system is further demonstrated in a project carried out in 2011 involving 31.1 km of urban roads on the Copperbelt, Zambia known as the ‘Formula 1 Lot 4’ project. The summary of the bids received under this project is shown in Table 1.1.

Table 1.1: Formula 1 Lot 4 bid summary

S/No.	Name	Total sum in ZMW	Project rate per km
1.	Contractor A	75,623,454.16	2,431,622.32
2.	Contractor B	89,723,044.16	2,884,985.34
3.	Contractor C	198,509,008.27	6,382,926.31

It was noted that the difference in bids was as high as 162 percent. Even the second lowest bidder was 16 percent above the lowest bidder. Further examination of the unit prices for different work items revealed an even larger disparity of around 2000 percent. Table 1.2 indicates unit rates for selected items that showed disparities.

Table 1.2: Unit Prices with huge disparities in Formula 1 Lot 4 Bids

S/No	Description	Unit	Rate 'ZMW		
			A	B	C
1.	150mm compacted pavement layer	m3	45.76	105.00	147.00
2.	Crushed stone base	m3	10.00	222.50	36.75
3.	Road-marking: white lines	km	2,788.50	8,866.50	14,700.00

Without guidelines or an Engineer's Estimate, it would be difficult to select a contractor from Table 1.1 that would provide VfM. Stakeholders require confidence and assurance of the validity of the estimate as a predictor of ultimate cost when the project is eventually constructed. Furthermore, the absence of construction specific cost indices has for some time now hindered the development of software based cost estimation models specific for Zambia. Regular formal publication of production rates for plant and construction workers are non-existent. The construction sector has in the past used the Consumer Price Index (CPI) as a basis for cost estimation. However, if CPI is not applied appropriately, it could result in inaccurate road infrastructure cost estimates.

1.3 Rationale

The national roads system in Zambia was experiencing increased activity following rise in public spending in the sector and institutional reforms designed to enhance efficiency of the road sector. The roads' share of Gross Domestic Product (GDP) increased from 1.5 to 4.1 percent in two years in 2010 – 2012 (Raballand & Whitworth, 2012). In

September 2012, Zambia made its inaugural entry on the international capital market and raised US $750 million, at a price that was one of the lowest ever for a debut issue for a Sub-Sahara African country. US $430 million, accounting for 57 per cent of the Eurobond was budgeted for road and rail transport (Government of the Republic of Zambia , 2012). In view of the foregoing a number of programmes were launched namely:

i. the Link Zambia 8000 launched in September, 2012 whose aim was to link all provincial capitals and open up the country to investment, particularly in rural areas to enhance accessibility to markets by upgrading 8000km of major roads across Zambia within a five year period from 2012 – 2016 (RDA, 2012b);

ii. the Pave Zambia 2000 involving the rehabilitation of approximately 2,000 km of township roads using environmentally friendly, labour-intensive paving block and cobblestone was also launched in 2012 (RDA, 2012a);

iii. the L400 programme whose construction and rehabilitation of approximately 400km of Urban Roads in Lusaka, Zambia commenced in June 2013(RDA, 2012b); and

iv. the ring road construction in Lusaka in compliance with the 2009 Comprehensive Urban Development Plan for City of Lusaka, Zambia (JICA, 2009).

There was concern as to whether the road sector in Zambia was operating efficiently and if it could handle the rising changes effectively. The road sector was perceived to exhibit high margins of profit. Consequently, key stakeholders have called for an informed position on prevailing market rates in the Zambian construction industry. As a result attention has been focused on pricing of construction unit rates.

One of the common approaches to cost estimation in Zambian road sector is the unit cost estimating. Hendrickson (2008) describes the unit cost estimation approach as where a unit cost is assigned to each task as represented by the bill of quantities and the total cost is the summation of the products of the quantities multiplied by the corresponding unit costs.

Typically, road construction can be considered as a combination of direct and indirect parameters. The difference between actual direct costs or central parameters and prevailing market rates in this study is referred to as the 'economic strata' or 'cost structure' which reflects the peculiarities of the local setting usually qualitative in nature such as prevailing project conditions, competition and other risk factors. Determining the economic strata using artificial neural network was an appropriate method as the relationship between the variables or factors could not be expressed by a simple mathematical relationship. Neural networks mimic human intelligence and decisions are made based on historical trends and the training received.

The UCEM provided a framework within which to assess the economic strata and also shed light on cost factors that account for cost variations across projects. The reasons for unit rate analysis are many. Among them are: regulatory and pricing requirements; labour and management perspectives; and investment decisions about the optimal mix of inputs to employ in the production process. Construction regulatory bodies require reliability in estimation of project costs to understand prevailing market rates in the Zambian road sector.

The development of estimates with theoretical and mathematical methods makes development of CURs more scientific and objective. Using artificial neural network to predict the perceived change from the central parameters provides a structured process to an otherwise unclear and ill-defined method of unit cost estimation. Ultimately, the UCEM creates a bridge between the existing parametric mathematical models and a country's road cost structure. Neural networks have been used in determining conceptual estimates with accuracy of around ±20 percent. Use of neural network for definitive estimates is limited. The UCEM integrates neural network to base rates to derive unit rates in the absence of construction specific cost indices. The UCEM provides a standardized procedure of pricing road activities in Zambia, to ensure uniformity in public and private procurement practice.

1.4 Theoretical framework

Unit cost comparison for specific tasks is a sound method as it reduces cost variations that arise because of site differences (Econtech, 2007). Good construction management must vigorously pursue the efficient utilization of labour, material and equipment. Improvement of labour productivity should be a major and continual concern of those who are responsible for cost control of road infrastructure. Material handling, which includes procurement, inventory, shop fabrication and field servicing, requires special attention for cost reduction. The use of new equipment and innovative methods has made possible wholesale changes in construction technologies in recent decades (Hendrickson, 2008). Organizations which do not recognize the impact of various innovations and have not adapted to changing environments have justifiably been forced out of the mainstream of construction activities. Therefore, the assumption was that Zambia as a country had not recognized the impact of various innovations. Consequently, it had not adapted to the changing environment resulting in being forced out of the mainstream of construction activities causing CURs to be unjustifiably high.

This led to the hypothesis that the high variance in CUR was as a result of inferior work practices leading to shoddier work and reduced monetary value or a case of contractors taking advantage of the situation due to lack of a pricing mechanism.

Therefore, a detailed investigation into individual road construction activities and factors that affect roadwork such as labour productivity data, taxation, environmental issues, capacity and size of the construction firm was required to come up with a pricing mechanism. The pricing mechanism is essential for planning and comparison purposes. Ultimately it should provide a guide and give confidence that the various stakeholders are getting value for money and that no one was taking advantage of the other. The effectiveness of the pricing mechanism depended on whether all factors were considered and the flexibility of the model to estimate the impacts of the activities on the road sector in a particular country. The modelling sought to provide estimates of permanent long-term gains in activity in the ZRS and other industries from having a more productive construction industry. It also estimated the permanent long-term follow-on benefits to consumers in the form of lower prices. The analysis of the evolution of the cost differences between tasks in various countries indicated that the model was likely to have a significant impact on stakeholders in terms of obtaining value for money in road infrastructure development. This led to the formulation of the aim and objectives of the study.

1.5 Aim and objectives of the research

The main aim of the research was to develop a construction unit cost estimation model (UCEM) for road-works incorporating neural networks to provide a standardized procedure of pricing road activities in Zambia and help understand prevailing market rates in the Zambian road sector.

To achieve the main aim, the objectives of the study were to:

a) establish the major cost factors that constitute construction unit rates for road-works in Zambia;
b) determine the appropriate application of the neural network architecture to the established cost factors;
c) investigate unit rate build up from first principles of Southern Africa Transport and Communications Commission (SATCC) pay items;
d) integrate neural network results with first principles build-up in UCEM development;
e) establish a database where variables can be stored and updated when required; and
f) validate the UCEM with other SADC countries that use SATCC specifications.

1.6 Research methodology

The study focused on unit cost estimation and the six steps of cost estimation were adopted as a general guideline as shown in Figure 1.5.

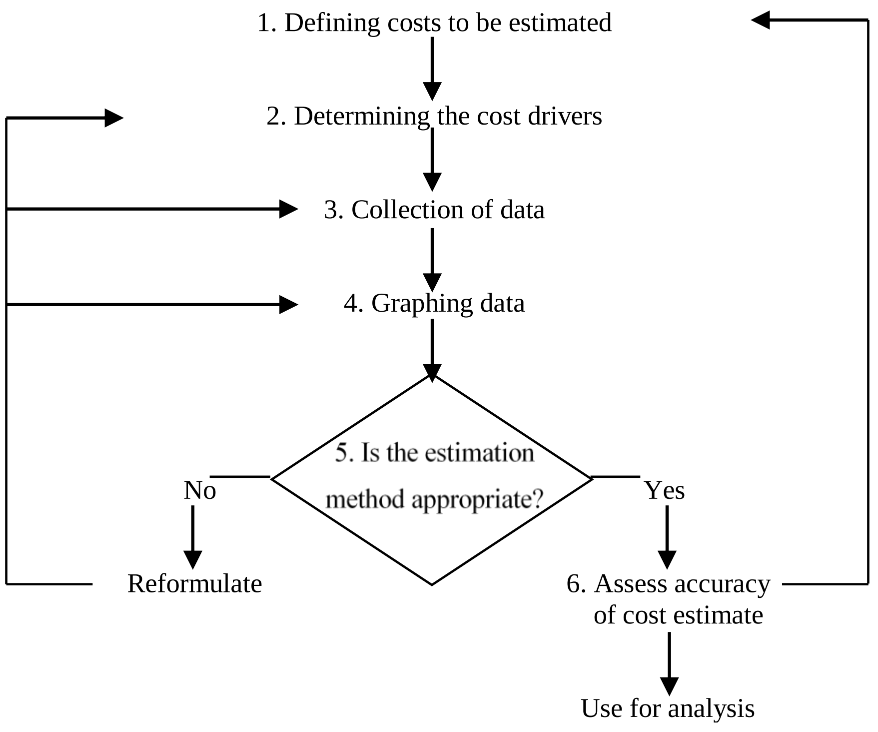


Figure 1.5: Steps in cost estimation
(After Blocher et al., 2008)

1.6.1 Literature review

Literature review was the main focus on defining costs to be estimated. It included review of relevant books, journals and conference papers with regards to current local and foreign cost factors that influence unit rates. Due to scarcity of literature on neural networks in Zambia, the internet was the main electronic source for secondary data.

1.6.2 Expert opinion survey

To determine the cost drivers, expert opinion was used. Expert opinion adopted the partial Delphi technique. Expert opinion was sought from key players with wide experience in the Zambian road sector regarding factors that influence unit cost in road-works.

1.6.3 Questionnaire surveys

A self-administered questionnaire was used to collect additional primary data. The targeted respondents were civil engineers and quantity surveyors from various sectors of the ZRS namely: the clientele; consultancy; contractor; manufacturing; and material suppliers.

1.6.4 Data analysis

The Pareto analysis and Statistical Package for Social Sciences (SPSS) factor analysis were used to determine the relevant cost factors by analysing the correlation between the variables. For the neural network, NeuroShell2 was selected because of its classic neural network paradigms. The Kohonen architecture was used for training because it is unsupervised and has the ability to learn without being shown correct outputs in sample patterns.

1.6.5 Model development

The neural network training results were integrated with the base rate in the development of the model. Using ASP.NET 4 with the C# programming language and Microsoft SQL Server 2012 as the database engine the model produced varied unit cost rate depending on the location of the project.

1.6.6 Validation

The UCEM was validated locally and regionally using real systems measurement, expert intuition and theoretical results analysis.

1.7 Significance of the study

Neural networks are a relatively new research area to tackle cost estimation challenges in road infrastructure delivery in Zambia. There was little or no documentation of previous effort of developing a UCEM integrating neural networks for road-works. Development of the UCEM was one of the ways to rationalise Zambia's perceived high road infrastructure costs.

There are various systems for building up unit rates in use in the Zambian road sector by both consultants and contractors. Both consultants and contractors have developed their own databases of unit rates from past contracts. Though some systems have been developed in the past primarily on an ad-hoc basis and for specific types of roadwork, these systems do not appear to be in regular use (RDA, 2009). Internationally, there are various unit rate build-up software available which accurately estimate the direct costs but usually allow a percentage mark-up to incorporate the economic strata. The model incorporates some of these standards in establishing base unit rates.

The UCEM provides a standardised procedure of pricing road activities in Zambia, to ensure uniformity in public and private procurement practice. It would assist those involved with project estimates to avoid misinterpretation of the quality and value of the information available to prepare cost estimates, the various methods employed during the estimating process, the accuracy level expected from estimates, and the level of risk associated with estimates. Finally, it was hoped that the model would provide a generic acceptable rate analysis system that can be used as a basis to compare against future projects. Increased client confidence would ensure improved investment in the industry and ultimately lead to more road construction activity in the country.

1.8 Organisation of the thesis

The thesis is organised into nine chapters falling under three categories: theory, practical application; and results. Chapters One, Two and Three focus on the underlying theory and concepts adopted in developing a UCEM. The practical application in Chapters

Four, five and Six consider requirements such as the number of pay items used in the Zambian road sector, establishment of the eight factors and how information regarding the factors can be collected as input into the neural network. The last three, Chapters Seven, Eight and Nine present results by assessing and validating the accuracy of the cost estimate. The structure of the thesis in chapter form is indicated in Figure 1.6.

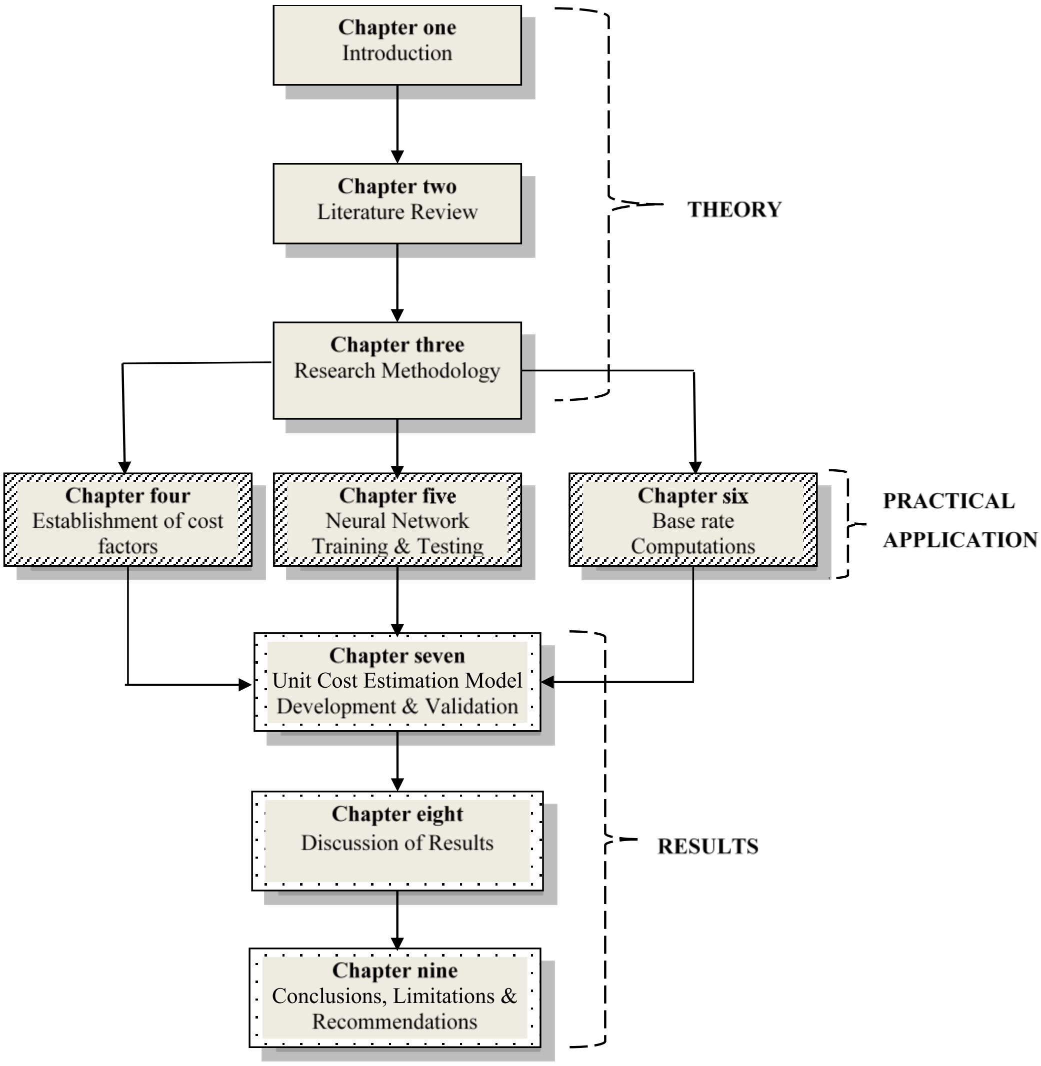


Figure 1.6: Layout of chapters

Each chapter is summarised below.

Chapter One serves as an introduction to the research. The chapter provides the background of the research, statement of the problem, aims and objectives of the study, research methodology and significance of the research.

Chapter Two outlines the review of literature concerning factors affecting unit rates in the construction industry, neural networks and how they have been used in similar studies.

Chapter Three explores available research methods focusing on their advantages and disadvantages and their adequacy to achieving the specific objectives of the research. Appropriate research instruments were then recommended for this study.

Chapter Four details how the expert opinion panel and questionnaire survey were carried out to establish cost factors for the Zambian road sector.

Chapter Five focuses on the neural network, selection of its architecture and training criteria. Results of the training are presented and compared to test cases.

Chapter Six draws attention to how the base rate was built up using labour material and machinery and compares with the prevailing market rates. It focuses on contentious pay items such as overhaul and restricted haul.

Chapter Seven details the development of a unit cost estimation model and its validation with five SADC countries. The model is web based and the output is unit rates for each pay item.

Chapter Eight discusses the results from Chapters Two to Seven indicating the research contribution.

Chapter Nine presents conclusions, recommendations and limitations directed at areas for further studies.

1.9 Summary

This chapter presented the background, aim and objectives of the study. The problem statement was that lack of a standardized procedure of pricing road activities in Zambia led to huge disparities of about 2000 per cent on similar road tenders as it was not clear what constituted CUR in the Zambian road sector. The assumption was that a high variance in CUR was as a result of inferior work practices leading to shoddier work and reduced monetary value or a case of contractors taking advantage of the situation due to lack of a pricing mechanism. Chapter two examines existing cost estimation models. It considers various studies conducted in the field of non-parametric cost estimation, comparing neural networks to regression analysis for highway cost estimation.

Chapter Two: Literature Review

2.1 Introduction

Chapter One presented the background, problem statement, aim and objectives of the study. The statement of the problem highlighted that lack of a standardised procedure of pricing road activities in Zambia resulted in disparities of as high as 2000 percent on tenders. It was also not clear what constituted CUR in the Zambian road sector. This chapter examines existing cost estimation techniques of paved and unpaved roads. It considers various studies conducted in the field of non-parametric cost estimation comparing neural networks to regression analysis for building cost estimation.

2.2 Southern African Development Community road network

Zambia is in Southern Africa and belongs to the Southern African Development Community (SADC). Of the fifteen (15) SADC member countries, six (6) are landlocked and Zambia is the largest of these. As a centrally located country in Southern Africa, Zambia is in a position to become both a continental and regional hub and gateway for integrated, safe, secure and efficient infrastructure capacity along strategic transport and development road corridors (GRZ, 2010). As industries and economies develop throughout the Southern Africa region, use of the transport network will exceed its current capacity (SADC, 2012a). It is predicted that by 2030, traffic for landlocked SADC countries will increase to 50 million tonnes, ramping to 148 million tonnes by 2040, an 8.2 percent annual growth rate (SADC, 2012a). This is phenomenal and Zambia is strategically located to benefit from the traffic generated on the regional road trunk network.

In 2001, it was estimated that about 50 percent of the paved main road network in SADC was in good condition, with the remainder classified as only fair or poor (SADC, 2012a). Botswana, Lesotho and Namibia had particularly good road standards and about two-thirds of South African and Zimbabwean roads were in good condition. In Malawi, Swaziland and Tanzania about 55 percent of roads were in good condition but the proportion was lower in Zambia at 40 percent (SADC, 2012a). This situation is further emphasised in Figure 2.1 which shows Zambia as being one of the countries in the region with very poor roads.

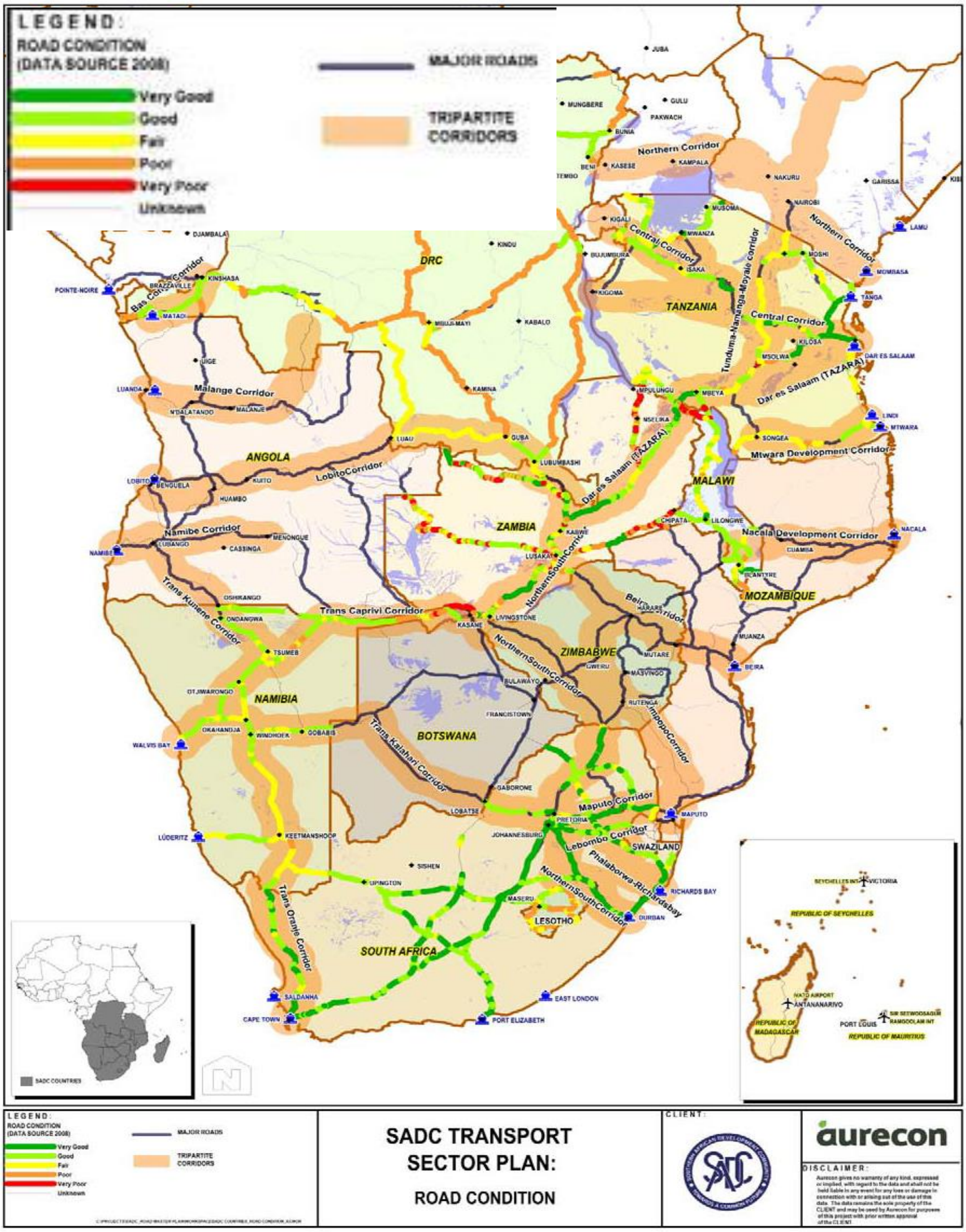


Figure 2.1: Road conditions in SADC countries
(Source: SADC Sector Plan, 2012a)

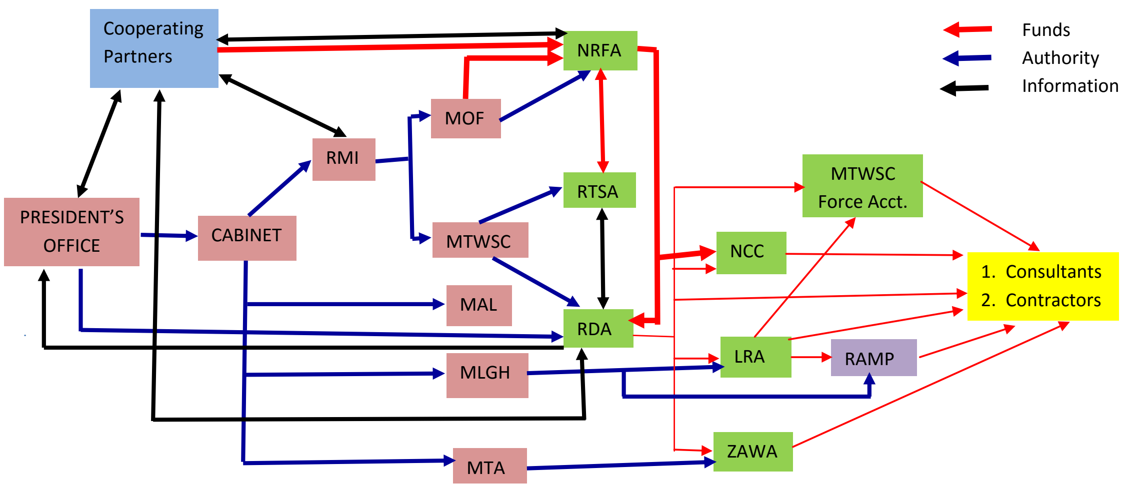
Figure 2.1 shows South Africa as a country with very good trunk roads. South Africa could, therefore, be used as a benchmark for SADC and in particular by Zambia regarding lessons learnt on provision of a good road network. For instance, Zambia does not have any tolled freeways which are functioning in South Africa.

2.2.1 Zambian road sector

Zambia is a land locked country. The GRZ has prioritised road infrastructure to make the country "land linked". The World Bank (2015) described Zambia as a lower middle income country. It is an entirely landlocked country covering an area of 752,620 km^2 with an estimated population of 13,092,666 as at 2010 population census, and as such depends on cost-effective and efficient road transport links for both its imports and exports as well as for transit traffic. The GRZ (2010) indicated that the Zambia road sector had a total road network of 67,671 km of which 40,265 km formed the Core Road Network (CRN). Further, about 9,403 km of the core road network was paved and the rest was unpaved. Of the total road network, 37,000 km was gazetted while 30,000 km was un-gazetted. The density of the core road network was 0.053 in km/square and 0.029 in km/capita. The collapse of the rail network through the years led to most of the heavy loads traditionally meant to be carried on railways being conveyed by roads thereby placing tremendous stress on the CRN and increasing road maintenance costs.

A pro-active approach from GRZ to promote investments in transport and distribution infrastructure led to commercialisation of the road sector in 2002.Three agencies established in 2002 were: Road Development Agency (RDA); Road Transport and Safety Agency (RTSA); and National Road Fund Agency (NRFA).Though the RDA was responsible for road construction and maintenance in the country, Local Road Authorities (LRA), under Ministry of Local Government and Housing (MLGH)were responsible for roads in their respective districts.

The budget for construction, rehabilitation, and maintenance of local authority roads depended on the national budget through NRFA. The Road Sector Annual Work Plans (RSAWP) prepared by LRAs for urban roads are submitted to MLGH for compilation. Review and finalisation of the RSAWP is done by RDA based on the budget guideline from NRFA. Figure 2.2 shows the functional relationship of the Zambian road sector stakeholders.



Key

LRA	Local Road Authorities	NCC	National Council for Construction
MAL	Ministry of Agriculture and Livestock	NFRA	National Road Fund Agency
MLGH	Ministry of Local Government and Housing	RAMP	Rural Accessibility and Mobility Programme
MOF	Ministry of Finance	RTSA	Road Transport and Safety Agency
MTA	Ministry of Tourism and Arts	ZAWA	Zambia Wildlife Authority
MTWSC	Ministry of Transport, Works, Supply and Communication		

Figure 2.2: Functional relationship of the road sector players

The Zambian road sector has been using the Southern Africa Transport and Communications Commission (SATCC) design standards and specifications for roads and bridges 1998 which are still in draft form. The SADC was in the process of overseeing an effort aimed at harmonising road standards such as: SADC Specification for Road and Bridge works also translated into both French and Portuguese; SADC Guideline on Low-volume, Sealed Roads; SADC Geometric Design Standards; SADC Pavement Design Manual; and SADC road traffic signs, markings and signals (ASANRA, 2008). It was not clear how far this effort had been achieved but bilateral agreements posed a challenge regarding practical application and management of the terms and provisions. Generally, policies and efforts in the Zambian road sector were targeted towards the transformation of Zambia into a truly "*landlinked*" country in the sub-region.

The SATCC standards and specifications specify a method of measurement of road activities through stated pay items. The selected pay items for a particular project together with drawings are used to determine the project cost estimate. The cost estimate of a proposed road project is one of the key determinants in evaluating the economic viability and business case of the new investment. The estimate not only establishes a project budget, but plays an equally important role in the control phase of a project. An effective estimate must provide accurate information for cost monitoring and progress measurement of a project during execution.

2.3 Cost estimation

Estimation is the engineering art of developing an informed or scientific prediction about the cost and delivery date, and establishing all the resources required by the project (Steyn et al., 2006: 173). Cost estimation is essentially a computational process that attempts to predict the final cost of a future project, even though not all of the parameters and conditions are known when the estimate is prepared (AACE, 2013). Cost estimation eventually leads to Cost Estimate Classification. Cost estimation does not mean forecasting the exact cost of the project, but rather achieving a final cost that is within the accuracy level that is defined by the class estimate for each stage of the project.

2.3.1 Types of estimates

Cost estimating methods differ at various stages of a project life cycle. Estimates are generally divided into two types, namely: order of magnitude estimate; and definitive estimate.

i. Order of magnitude estimate

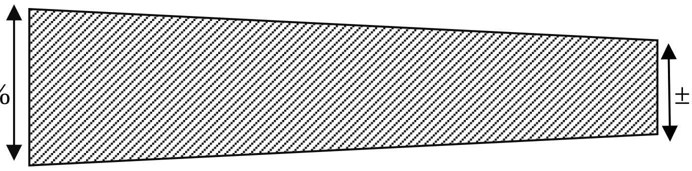
Order of magnitude estimate or a conceptual cost estimate is defined as the forecast of project costs that is performed before any significant amount of information is available from detailed design and with incomplete work scope definition, with the purpose of using it as the basis for important project decisions and the appropriation of funds (Elbeltagi, 2015). Conceptual estimates are made during the early phases of the project when budgets are to be drawn up and available information is minimal. No working drawings or detailed specifications are available at this stage. Therefore, such an estimate relies on the cost data of similar facilities built in the past.

ii. Definitive estimate

The definitive or engineer's estimate is made when the scope of work is clearly defined and the detailed design is in progress so that the essential features of the facility are identifiable. This estimate is based on the completed plans and specifications when they are ready for the owner to solicit bids from contractors. In preparing these estimates, the engineer will include expected amounts for contractors' overheads and profits.

Ayed (1997) described four estimate types during the life cycle of a project as preliminary, elemental, unit price and detailed. The characteristics of these estimate types are summarised in Table 2.1.

Table 2.1: Estimate types throughout a project's life cycle

Estimate Type	Preliminary	Elemental	Unit Price	Detailed
Project Phase	Concept	Preliminary Design	Detailed Design	Construction
Available information	Limited →	→	→	Detailed
Difficulty level	High →	→	→	Low
Expected Accuracy	±20% 			±10%

(Source: Ayed, 1997).

Table 2.1 shows that a conceptual estimate has an acceptable accuracy of ±20% compared to a detailed estimate which is expected to have an accuracy of ±10%.

Cost estimating invariably leads to cost estimate classification. The classification guideline is required to avoid misinterpretation of: the quality and value of the information available to prepare cost estimates; the various methods employed during the estimating process; the accuracy level expected from estimates; and the level of risk associated with estimates (AACE, 2011). According to AACE (2011), Cost Estimate Classification System categorises five cost estimate classes where Class 5 estimate is based upon the lowest and a Class 1 estimate is closest to full project definition and maturity. This classification was determined from benchmarking industry practices which established that three to five discrete categories were appropriate. The AACE International cost estimate classification is shown in Table 2.2.

Table 2.2: Cost estimate classification

	Primary Characteristic	*Secondary Characteristic*			
ESTIMATE CLASS	**MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES** Expressed as % of complete definition	**END USAGE** Typical purpose of estimate	**METHODOLOGY** Typical estimating method	**EXPECTED ACCURACY RANGE** pical+/- rangerelativetoi ndexof1(i.e. Class1 estimate)[a]	**PREPARATION EFFORT** Typicaldegree ofeffortrelative toleastcostinde xof1[b]
Class5	0%to2%	Screening or feasibility	Stochastic (factors and/or models) or judgment	4to 20	1
Class4	1%to15%	Concept study or feasibility	Primarily stochastic	3to 12	2to4
Class3	10%to 40%	Budget authorisation or control	Mixed but primarily stochastic	2to6	3to 10
Class2	30%to 75%	Control or bid/tender	Primarily deterministic	1to3	5to 20
Class1	65%to 100%	Check estimate or bid/tender	Deterministic	1	10to100

Notes: [a] if the range index value of "1" represents +10/-5%, then an index value of 10 represents +100/-50%.
[b] If the cost index value of "1" represents 0.005% of project costs, then an index value of 100 represents 0.5%.

(Source: AACE, 2011)

Unit cost estimating, aided by sound engineering judgement, is the most definitive estimate technique and uses information down to the lowest level of detail available (Hendrickson, 2008). This is the most common approach to cost estimation used in Zambia. Hendrickson (2008) described the unit cost estimation approach as where a unit cost is assigned to each task as represented by the bill of quantities and the total cost is the summation of the products of the quantities multiplied by the corresponding unit costs. A study carried out by Mashilipa (2004) investigated various cost estimation methods used in the Zambia construction industry. It revealed that the most common method was the use of rates based on past contracts with an allowance for inflation followed by building up of unit rates from first principles and finally the use of computer software. Mashilipa (2004) observed that the use of previous tender rates was common because of lack of experienced cost estimators in the bidding firms and the reduced duration of coming up with an estimate. This trend in Zambia indicated that estimate accuracy was the least requirement by the bidders perhaps due to the lack of cost estimate accuracy classification as established by professional quantity surveying bodies in other countries.

2.3.2 Unit rate build up software

There are various unit rate build up software available in the world which accurately estimate direct costs but usually allow a percentage mark-up to take care of the economic strata. Some of the software includes:

a) 4Clicks Project Estimator by 4 Clicks-Solutions, LLC;
b) D-Profiler by Beck Technology;
c) Hard Dollar by Hard Dollar Corporation;
d) Cleopatra Enterprise by Cost Engineering;
e) Cost Link – AE by BSD – Building Systems Design, Inc.;
f) CMS – Construction Management Software;
g) Corecon V7 by Corecon Technologies, Inc.;
h) EuroJOC by CorVet Systems;
i) MOCA Build and MOCA Manage by MOCA Systems;
j) ProEst Estimating by ProEst;
k) Sage 300 Trade Specialty (formerly Sage Timberline Enterprise) by Sage Timberline office;
l) Construction Suite CM by UDA Technologies;
m) iTWO by US Cost Inc.;
n) WinEst by Win Estimator, Inc.;
o) IBM Tririga Capital Projects Manager by Tririga;
p) Oracle Primavera P6 EPPM software;
q) Heavy Bid, from Construction Software developer HCSS;
r) Earthwork software systems by Tally Systems; and
s) ProContractor MX, by Maxwell.

It was not clear which software was commonly used amongst contractors and practitioners in the Zambian road sector as no published research could be cited.

2.3.3 Cost estimating methods

The AACE (2013) described parametric estimates as estimating algorithms or cost estimating relationships that are highly probabilistic in nature such that the parameters or quantification inputs into the algorithms tend to be abstractions of the scope. Typical parametric algorithms include, but are not limited to: factoring techniques; gross unit costs; and cost models that are algorithms intended to replicate the cost performance of a process of a system. Parametric estimates could also be as accurate as definitive estimates. Though Black (1984) stated that parametric estimating may mean different things to different researchers, the usual distinction from traditional estimating techniques seems to involve the use of aggregated systems in the estimates instead of building up the estimate from its components. Whereas parametric cost estimating methods often lead to a mathematically-fitted function called a cost estimating relationship (CER), non-parametric methods do not require CER. The parametric method of cost estimating uses statistical techniques such as regression analysis to find a functional relationship between changes in cost and the factors upon which the cost depends (De la Garza and Rouhana, 1995). A parametric model is a functional model that mathematically describes the cost of a structure, module, or a system as a function of one or more independent variables. Figure 2.3 indicates various types of cost estimating techniques used in the construction industry.

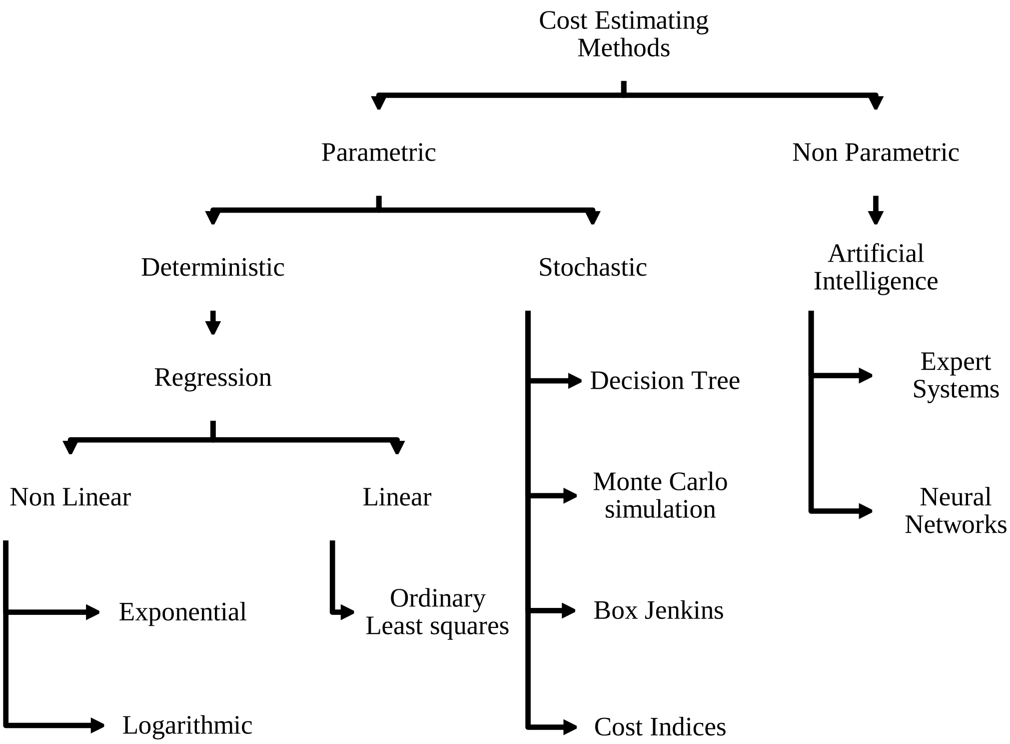


Figure 2.3: Types of cost estimation methods used in the construction industry

2.4 Neural networks

Neural networks are non-parametric. They are a form of artificial intelligence capable of capturing the relations between independent and dependent variables. Simply put a neural network consists of a minimum of three layers: an input layer; an output layer; and a hidden layer as shown in Figure 2.4

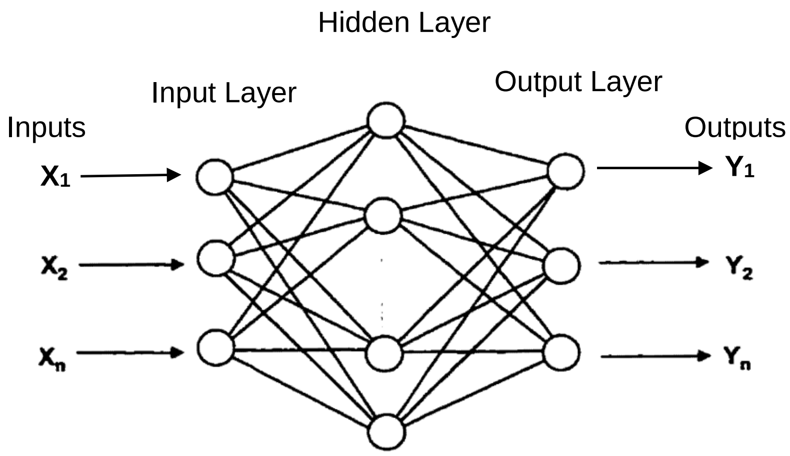


Figure 2.4: Basic 3 layer NN architecture
(After Ayed, 1997)

One of the most important characteristics of neural networks is their ability to learn and self-organize (de la Garza and Rouhana, 1995). Neural networks similar to the regression analysis require the historical data of cost and data of variables influencing the cost. The neural network is trained with the historical data of the past projects so that it can capture the relations between variables and cost. The neural network is then used for cost estimation after training is completed.

There have been several citations from the literature on the use of neural network models to assist with cost estimation decisions in construction. Al-Tabtabai, et al. (1999) developed a neural network model that could be used to estimate the percentage increase in the cost of a typical highway project from a baseline reference estimate. Moselhi and Siqueira (1998) developed an automated cost estimating system for structural steel framing that provided quick cost estimates, and facilitated negotiations with owners and permitted the checking of detailed cost estimates prepared at a later stage. Work that specifically compares neural network to regression models for cost estimation includes material cost estimation of carbon steel pipes by de la Garza and Rouhana (1995) and the performance, stability and ease of cost estimation modelling to develop CERs by Smith and Manson (1997). In both studies, results showed that neural network were advantageous over parametric approaches.

Bode (1998) stated that neural network produce better cost predictions than conventional costing methods. Bode (1998) further said neural network do not require the relationship between attribute values and cost to be direct. In addition, neural network learn “from scratch” by detecting hidden relationships among training data. In contrast, parametric methods require the specification of a cost function type before its parameters are estimated. Neural networks outperform regression linear models given the same training data and the same variables (Setyawati et al., 2003). Artificial neural networks allow self-learning, self-organization, and parallel processing, and are well-suited for problems involving matching input patterns to a set of output patterns (Al-Tabtabai, et al., 1999). However, Moselhi and Siqueira (1998) noted that neural network also had their own shortcomings: they require in-depth technical knowledge in both the problem to be solved and in the development of neural network applications; are not transparent enough to provide explanation facility or rationale to the solution generated; and are sensitive to the organization and preparation of the data used in training. Nonetheless, in the last decade, neural networks have become powerful tools for investment forecasting and have achieved impressive results (Setyawati et al., 2003). Neural networks have been applied in financial forecasting, hotel industry applications, travelling problems, and environmental science applications. Setyawati et al. (2003) further stated that compared to traditional statistics, neural networks had been successful in many domains.

2.4.1 Neural network architecture

The selection of the neural network architecture is an important step to ensure that the model produced the least percentage error. Setyawati et al. (2003) stated that choosing the right neural network topology for use in a particular domain with optimum generalization performance was not a trivial problem. There was no fixed rule to determine the appropriate architecture or its parameter values.

i. Types of networks

a) Supervised

Supervised networks make predictions or decisions according to other patterns of inputs and outputs learnt. In a supervised network, the network learns how to make predictions, classifications, or decisions by giving it a large number of correct classifications or predictions from which it can learn(Ward systems, 2014)..

b) Unsupervised

Unsupervised networks classify a set of training patterns into a specified number of categories without being shown in advance how to categorize. The network uses clustering patterns. However, occasionally the network may not be able to separate the patterns into that many distinct categories (Ward systems, 2014).

ii. NN design

From literature, one of the commercial software used for design and training of neural network model was NeuroShell2. NeuroShell2 was selected because of its classic neural network paradigms, its popularity amongst researchers and its user friendly graphical user interface (GUI) (Garson, 1998). Figure 2.5 shows a screenshot of GUI of NeuroShell2.

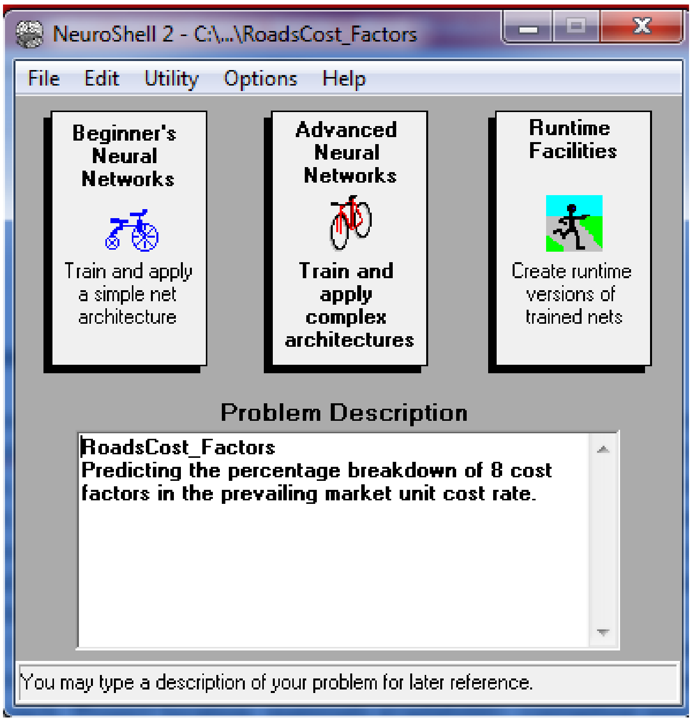


Figure 2.5: Screen shot of NeuroShell2 GUI
(After Ward System, 2014)

NeuroShell2 has five network architectures that include different learning paradigms namely: Back propagation (BP); Kohonen; Probabilistic Neural Network (PNN); General Regression Neural Network (GRNN); and Group Method of Data Handling or Polynomial Nets (GMDH Network). All the networks are of supervised type, trained with both inputs and outputs except the Kohonen network (Ward systems, 2014).

A three layer back propagation neural network is the most effective for most applications (Ward Systems, 2014). Ward systems (2014) further stated that three layer back propagation was used in 95 percent of the working neural network applications and trained much faster than 4 or 5 layer networks. However, a back propagation network called a recurrent network is excellent for time series data.

For sparse training data to be separated into categories, a Probabilistic Neural Network (PNN), known for its ability to train very quickly and work on sparse data is the most appropriate (Ward Systems, 2014). Like PNN networks, General Regression Neural Networks are known for their ability to train quickly on sparse data sets. Ward Systems (2014) indicated that GRNN respond better than back propagation to many types of problems. The Kohonen Self Organizing Map is useful in clustering data. Because it is unsupervised, what is required is the number of desired categories. Moselhi and Siqueira (1998) stated that back propagation is the training algorithm most commonly used for the development of civil engineering, and more specifically construction management applications.

Setyawati et al., (2003) established that one hidden layer gave a lower percentage error than either two or three hidden layers. The number of hidden nodes that gave the best results was four and the lowest percentage error was obtained using 60 percent of the data as the training set. The tangent (tn) activation function gave better results than the sigmoid (sig) or linear activation functions.

iii. Training data

Neural networks are not programmed but trained (Setyawati et al., 2003). In order to be immediately useful, a neural network must be trained before actually being applied. Training is an estimation of a neural network model. The goal of the training process is to find the parameters of the neural network model, which are called connection strengths or network weights that reduce model errors. In general, there are two types of learning or training in a neural network: supervised and unsupervised (Setyawati et al., 2003). In supervised training both the inputs and outputs for a dataset are presented to the network during the learning process. Each processing unit receives a number of inputs, then each input is multiplied by a corresponding weight, and all the weighted inputs are then summed to determine the activation level of the processing element. At the end of each cycle or iteration, the network evaluates the error between the desired output and actual output, and then uses this error to shift the connection weights according to a "learning rule" in what is generally referred to as back-propagation (Setyawati et al., 2003). For a certain number of learning cycles, the weights are shifted until the deviations from the desired outputs are minimized. Setyawati et al. (2003) established that the lowest percentage error was obtained using 60 percent of the data as the training set.

2.5 Construction unit rate formulae

Generally, road construction works can be considered as a combination of two types of items. Firstly, those that can be estimated through some form of calculation, for example, the direct labour, material and equipment inputs. In this category the cost relationships between labour, material and plant are known. Secondly, indirect items such as those that cannot be calculated directly from labour, material and equipment costs. The difference between actual direct costs and prevailing market rates is referred to as the 'economic strata' or 'cost structure' which reflects the peculiarities of the local setting, usually qualitative in nature such as prevailing project conditions, contractor capacity and other risk factors. Even though construction cost factors may be identical internationally, it is the impact on the unit cost that varies according to a country's political, economic, social and technological inclinations. In this study the base rate was calculated from first principles while the economic strata was determined using neural networks. This could be represented mathematically as:

$$C_{UR} = B_R + R_{ES} \quad \text{Equation 2.1}$$

where:

B_R = Base Rate

R_{ES} = Economic Strata

C_{UR} = Construction Unit Rate or prevailing market rates

In traditional unit rate calculations, project-specific costs based on a detailed study of the resources, such as labour hours, material, equipment and subcontractor costs, or other unit-cost-type items required to accomplish each activity of work contained in the project work breakdown structure (WBS) or Bill of Quantities (BoQ) is undertaken. Indirect and overhead costs, contingency, and escalation are then added as necessary factors (Langdon, 2014). Drawings, specifications, and project scope are used to identify activities that make up the BoQ. Langdon (2014) stated that a BoQ serves three purposes: first and foremost it must be prepared with the objective of providing the estimator with as accurate a picture of the project as possible so as to provide a proper basis for pricing; second, it should enable the employer to compare tenders on an equal basis; and third it will be used to evaluate the work executed for payment purposes.

2.5.1 Estimating from first principles

Estimating from first principles or cost based estimating is the preferred method for heavy highway-type bidding by contractors. Because such estimates reflect the cost to construct the specified work in the most economical manner based on the contractor's capability and contract duration (Molenaar et al., 2011). Estimating from first principles requires careful review of work crews and equipment completing tasks at assumed rates of productivity. Bid items are broken down into detailed task-by-task work activities. The direct cost for each task is developed with separate costs for the labour, equipment, subcontractor, and material components of the work required to complete a task (Molenaar et al., 2011). By using the latest price data for materials, equipment and labour, an accurate estimate is produced unlike bid-based estimating that uses historical data. Since most contractors utilize this approach to prepare bids, it becomes advantageous to use the same estimating method to prepare engineer's estimates.

Although more time and skill are required in first principles estimating compared to historical data based estimating but once the appropriate labour and equipment production data sources and material price database is created, the process is routine and manageable. Molenaar et al. (2011) reported that the Pareto Principle which states that approximately 80 percent of the project cost is contained in 20 percent of the items was applied in first principles estimating. Therefore, first principles estimating was applied only for those items that comprise major portions of a project's cost.

2.5.2 Sources of unit cost-based estimating data

There is no official current publication of productivity data for the Zambian road sector. The absence of construction indices has, therefore, hindered the development of software based cost estimation models specific for Zambia. Production rates for plant and construction workers are virtually non-existent. This proved to be a challenge in this study. Other sources providing guidelines for calculating cost data such as RS Means Heavy Construction Cost Data, Means Heavy Construction Handbook, Spon's Civil Engineering and Highway Works Price Book 2014 and Spon's African Construction

Cost Handbook were used. Zambia was one of the thirteen countries featured in the second edition of Spon's African Construction Cost Handbook. However, using such data has to be done with caution as the information is for the specified locale.

Early documentation of building up rates from first principles still valid today acknowledged Spence Geddes whose work was first published in 1951. Geddes (1960) recorded data of plant and labour hours taken to produce one unit of work in question as hour constants. Hourly constants are not affected by any fluctuations in the hire rate of plant or labour rates of pay per hour (ibid). The hourly constants thus always remain up to date and only the rates of pay per hour changes. The unit cost of each input is multiplied by a productivity rate appropriate to the work item to arrive at the direct cost for the item such as the average output per hour of a piece of equipment or the amount of cement required for a cubic metre of concrete work. Productivity is an effective and efficient utilization of all resources: labour, plant, materials and management (Prokopenko, 1987). Productivity is expressed in many ways but generally as the ratio of output over input or of output to resources which are consumed to produce that output. A highway construction production rate is the quantity produced or constructed over a unit time period (Jiang and Wu, 2004).

i. Equipment

Construction equipment and tools form a major part of the base unit rate. Equipment is required to carry out the physical work and install material. Heavy construction equipment is critical for any construction project and is used extensively at construction sites to reduce labour cost and time. Heavy construction equipment includes four main categories: earthmoving; material handling; heavy construction vehicles; and other plant. Earthmoving machinery is a collective term used for a group of equipment. This typically includes excavators, loaders, bulldozers, crawler dozers, scrapers, and shovels. Out of the four major categories, earthmoving equipment held a majority market share of around 78 percent in 2012 (Markets and markets, 2013). The equipment manufacturers that hold a majority share of the global heavy construction equipment market include Caterpillar and John Deere & Co of the U.S., Komatsu and Hitachi Construction Machinery Co. Ltd of Japan, JCB from the U.K. and Volvo Construction Equipment of Sweden. (ibid). During the study period, it was not clear which equipment make was the most popular in the Zambian road sector as no published research could be cited. Productivity rates from various literature sources were used to determine the quantity of resources required to carry out the work. Depending on its size, equipment may be estimated on an activity basis or may be estimated for the duration of the project. In this study, equipment was estimated on activity basis. For instance, concrete and asphalt paving production are usually controlled by either plant capability or the intricacy of layout, which controls paver manoeuvres. The productivity of a paver can be determined based on factors such as the paver speed, the cycle time of the asphalt or concrete delivery trucks, and the number of trucks (Molenaar et al., 2011). Equipment costs included expenses to cover depreciation, repairs, taxes, storage and fuel requirements. Estimating manuals such as the Caterpillar Performance Handbook provide work outputs for most common equipment types, based on the assumption that they are properly utilized, and these figures form the basis of cost and time estimates.

ii. Labour

In construction, labour productivity is often expressed as a number of labour hours per unit of work, although it may also be expressed as the quantity of work performed by a crew during a standard eight-hour day (Muzamil and Khurshid, 2014). There is lot of research data available regarding labour productivity of high income or developed countries compared to developing ones. According to Yi and Chan (2013), there were 83 published research papers related to construction labour productivity by US, 18 by UK and 20 by Canadian researchers. As a result, developed countries have improved their construction output, whereas developing countries lag behind and have no basis to determine whether they are operating efficiently or not.

Lack of official labour production rates make it hard for planning engineers to come up with contract duration, work schedule, costs and load estimates and budget and cost control systems. Furthermore, underestimating or overestimating the required amount of labour to undertake an operation is costly. For example, if one (1) km of drainage trench was to be excavated for a pipeline and it was known that the average amount of material to be excavated was $2m^3$ in volume per metre length of ditch, and the productivity norm of the workers was set at $3m^3$ per day, then the project would be completed in one day with 667 workers. At the other extreme, it would take about three years with one worker. A more typical set-up would be a group of 48 workers deployed over 14 days. The critical figure is the productivity norm. Workers are commonly set tasks that equal these norms. If the task is underestimated by 30 per cent, i.e. $2m^3$ a day for excavation rather than 3 m^3 in the example above, the direct cost of the project would increase by 30 per cent. Conversely, if the tasks were overestimated, then much of the workforce would not be able to meet their targets and there would be considerable disruption and discontent on site as well as delays in project completion.

An attempt in Zambia to produce formal labour productivity rates was conducted by ILO/ASIST (2004) on behalf of the Roads Training School under the Ministry of Works and Supply. Productivity rates were part of the contractor's handbook for labour-based road works. However, these productivity rates could not be fully adopted and applied in the industry because of various reasons. Firstly, these were produced to assist inexperienced or small scale contractors in labour based estimating. Secondly the method of establishment of these rates was not clear and thus the rates have to be used with caution. These rates were developed to be used on labour based road projects. However, many roads under construction in the country were not labour based. Finally, the rates were developed ten years ago necessitating review to ensure accurate and up-to-date rates. The ILO has replicated these labour based productivity rates in many countries in Africa such as Kenya, Zimbabwe and Botswana (ILO/ASIST, 1998).

Literature on more comprehensive formal labour productivity rates for African countries was limited. The USA leads the world in both the production and use of labour productivity rates. Herbsman and Ellis (1995) revealed that approximately 88 percent of the states and provincial Departments of Transportation (DOTs) in the USA use production rates to estimate contract time. The DOTs in every state develop their own labour productivity rates used to determine contract duration for every road project in that state. DOTs usually engaged academicians in local state universities to evaluate and update the formal labour production rates. Furthermore, studies on how various factors affect labour productivity were undertaken so as to improve the accuracy of the predicted contract durations (Jiang and Wu, 2004; Harber, 1988; and FDOT, 2010).

The word labour has a poor connotation on project sites. In this study, construction worker or human resource encompassing direct, supervisory and management employees on project sites are used interchangeable with labour. In estimating human resource costs, the construction worker's base rate plus all payroll indirect costs were multiplied by estimated labour hours to generate the human resource cost. Typically, this sum was handled as a direct human resource cost. For ease of estimating, specified crew rates were developed. Crews vary in size and mix of skills. The number and size of each crew should be based on two factors: having sufficient workers to perform a task within the construction schedule time limits; and the available workspace (Molenaar et al., 2011). Once the crews are developed, the task labour costs can be determined based on the production rate of the crew and the labour wage rates. Estimated construction worker rates were obtained from the prevailing wage rates.

iii. Materials

Materials include permanent material incorporated in the final work such as the supply and delivery of pavement materials such as pipes and temporary materials not incorporated in the final work such as formwork and setting-out pegs. Prices of materials should include all the expenditures, including but not limited to royalties, crushing costs, and vendor profit. In road construction, the relationship of storage of material to activity area was critical. Hauling costs are to be estimated based on haul distance, truck capacity, loading and unloading time, driver wages, and truck expense. Contractors have varying stockholding policies. Apart from the capital used to purchase the material stored, a major consideration was that too little storage could result in delays awaiting materials to be delivered whereas too much storage could be expensive in terms of weather and security requirement on site (Chudley and Greeno, 2014). Consideration should be taken to make proper allowances for quantity discounts and inflation.

2.6 Cost factors

The economic strata or cost structure reflects the peculiarities of the local setting, usually qualitative in nature, such as prevailing project conditions, competition and other risk factors. Blocher et al. (2008) stated that in cost estimation, choosing cost drivers was the most important step since the model's accuracy is based on selecting the relevant and appropriate cost drivers. Therefore, selecting and assessing factors that account for cost variations across road construction projects in Zambia was critical to the study.

Literature identifies various factors that affect construction costs with varying impacts in different parts of the world. Table 2.3 summarises some of the top ten factors influencing cost estimation in different countries.

Table 2.3: Top ten factors influencing cost estimation in different countries.

Author	Enshassi et al. (2007)	Memon et al. (2010)	Elinwa AU and Buba SA. (1993)	Trombka Aron and Sarah Downey (2008)
Title	Contractors' Perspectives towards Factors Affecting Cost Estimation in Palestine	Factors Affecting Construction Cost Performance in Project Management Projects: Case of Mara Large Projects (Malaysia)	Construction cost factors in Nigeria	A Study of County Road Project Cost and Schedule Estimates
Factors	1. Location of project (hot areas) 2. Segmentation of Gaza strip 3. Closure of Gaza strip 4. Financial status of the owner 5. Increase in unit costs of construction materials 6. Experience of consultant engineer 7. Clarity and quality of drawings before tendering 8. Clarity and accuracy of information related to the project before execution 9. Number and classification of competitors in tendering 10. Tender's currency	1. Fluctuation in prices of materials 2. Cash flow and financial difficulties faced by contractors 3.Shortage of site workers 4. Lack of communication among parties 5. Incorrect planning and scheduling by contractors 6. Contractor's poor site management and supervision 7. Delay in Material procurement 8. Underestimate project duration resulting Schedule Delay 9. Unforeseen ground conditions 10. Low speed of decisions making	1. shortage of materials 2. financing methods and payments for completed works 3.poor contract management, 4. materials cost 5. fraudulent practices and kickbacks 6. the fluctuation of material prices	1. Project Scope: 2. Land Acquisition: 3. Utility Relocation: 4. Laws, Regulations, and Policies 5. Environmental Compliance: 6. Surrounding Development: 7. Nearby Road Projects: 8. Cost Increases/Inflation: 9. Fiscal Conditions: 10. Procurement Process:

From Table 2.3, the factors reveal an insight into the construction economic strata of the different countries. In Palestine, closure and blockade of borders indicate security concerns contractors experience where as in the USA, utility relocation is a major factor due to the developed nature of the country. Whereas fluctuation in prices of materials is a major factor in Malaysia, it is the shortage of materials that affect construction costs the most in Nigeria. In addition, the inclusion of corruption as a factor indicates an issue contractors have to deal with in Nigeria. It can be deduced from literature that periodic review of cost factors is essential because of countries constant political, economic, social and technological transformation.

The determination of cost factors in the Zambian road sector forms the basis of the UCEM developed in this study using neural networks. Even though there is no limit on the number of factors or variables to be used in neural network, Bode (1999) stated that the number of attributes assumed to have an effect on cost should be small because the architectural complexity increases with the number of attributes, requiring more training samples to reach a given accuracy, yet training samples are usually scarce in cost estimation. From literature review, the number of factors used in similar neural network studies are indicated in Table 2.4.

Table 2.4: Number of input cost factors for neural networks

S/No.	Author	Topic	Number of cost factors used
1.	Peško et al., 2013	A preliminary estimate of time and cost in urban road construction using neural networks	9
2.	Hasan Abu Jamous (2013)	Parametric Cost Estimation of Road Projects Using Artificial Neural Networks	9
3.	Muqeem et al., 2011	Construction labour production rates modelling using artificial neural network	5
4.	Krzysztof Schabowicz & Bozena Hola (2007)	Mathematical-neural model for assessing productivity of earthmoving machinery	5
5.	Emsley et al., 2002	Data modelling and the application of a neural network approach to the prediction of total construction costs	Network 1 – 5 Network 2 – 9 Network 3 – 41
6.	Al-Tabtabai et al., 1999	Preliminary cost estimation of highway construction using neural networks	9
7.	Moselhi and Siqueira, 1998	Neural networks for cost estimating of structural steel buildings	4
8.	Ayed, 1997	Parametric cost estimating of highway projects using neural networks	10
9.	Creese and Li, 1995	Cost estimation of timber bridges using neural networks	3

Table 2.4 indicates an average of 9.9 factors.

From literature review, 45 cost factors which affect unit costs were selected and categorised in terms of whether the impact was caused by the country, road industry, contractor conditions or project specifications. The major findings from literature are summarised in the following section.

2.7 Findings from literature

The major findings from literature were that:

a) a conceptual estimate has an acceptable accuracy of ±20% compared to a detailed or definitive estimate which is expected to have an accuracy of ±10%;

b) a cost estimate classification system with three to five discrete categories for the Zambian road sector to benefit from the proposed UCEM is recommended to avoid misinterpretation of the quality and value of the information available to prepare cost estimates, the various methods employed during the estimating process, the accuracy level expected, and the level of associated risk;

c) it was not clear which software was commonly used amongst contractors and practitioners in the Zambian road sector as no published research could be cited;

d) neural network produced better cost predictions than conventional costing methods. Neural networks proved advantageous over parametric approaches and have been used for conceptual cost estimation in highway projects;

e) NeuroShell2, a commercial software, was easy to use and popular amongst researchers;

f) back propagation was the training algorithm most commonly used for the development of civil engineering, and more specifically construction management applications. One hidden layer gave a lower percentage error than either two or three. The lowest percentage error was obtained using 60 percent of the data as the training set;

g) unsupervised networks classified a set of training patterns into a specified number of categories without being shown in advance how to categorize the data;

h) estimating from first principles was the preferred method for contractors bidding heavy highway-type work and was therefore advantageous to use the same approach in preparing engineer's estimates;

i) periodic review of cost factors is essential because of countries' constant political, economic social and technological transformations;

j) the number of influencing factors used in similar studies in neural network averaged 9.9 factors; and

k) SADC countries utilise SATTC specifications, therefore were easy to compare and validate like pay items. Landlocked SADC countries like Malawi and Zimbabwe were selected as they were likely to have similar road network requirements as Zambia. Tanzania was selected as it was the only east African country in SADC and was interesting to note how Zambia compared to it. South Africa as a SADC country with very good trunk roads was also selected as a benchmark for SADC and in particular Zambia.

2.8 Summary

Chapter Two examined a range of available literature on cost estimation models and use of neural networks in the construction industry. One observation made was the scarcity of literature on the use of neural networks in Zambia. This notwithstanding, the chapter reviewed available literature in the field of non-parametric cost estimation. Literature revealed that neural networks seem to obtain better results than regression analysis for construction cost estimation.

Table 2.5 summarises the literature that was reviewed and provides objectives of those studies, the methodology used and conclusion and comments in the form of a critique. Chapter Three examines the research methods employed to achieve the objectives of the study.

Table 2.5: Content analysis of reviewed literature

Author	Year	Title	Objectives	Methodology	Conclusions/Comments
Muzamil Abu Bakar and Khurshid Bilal	2014	Analysis of Labour Productivity of Road Construction in Pakistan	To help local construction experts to understand the problems faced by the workers during road construction based on the conditions and circumstances of Pakistan	Questionnaires	The study concluded that the basic needs of labourers must be fulfilled initially to expect good output results from them
Chudley Roy and Greeno Roger	2014	Building Construction Handbook 10th Edition	Perspective of construction principles including guidance, processes, associated design and legislation for construction and maintenance of housing and other low rise buildings	Explanatory	Adequately defines the construction processes. Existing practices benchmark development as a basis from which contemporary design and technology evolve.
Langdon Davis	2014	Spon's Civil Engineering and Highway Works Price Book 2014,	Provide current market cost guidance for civil engineering and highway works relating to CESMM3 and highways methods of measurement bill of quantities format.	Explanatory / Descriptive	Provides current detailed resource costing essential for unit rate build up from first principles.
RS Means	2014	Heavy Construction cost data 2014, 28th Edition	Provide most current and comprehensive construction cost data for large civil projects including marine, waterways, airports, highways and tunnels	Descriptive	Provides productivity rates, cost factors and comprehensive construction cost data required for building up rates from first principles
Peško Igor, Milan Trivunić, Goran Cirović, Vladimir Mučenski	2013	A preliminary estimate of time and cost in urban road construction using neural networks	Develop an integrated model for the preliminary estimation of the real cost and duration for urban road construction and associated landscaping.	Predictive	9 factors used namely: quantity of crushed stone (m^3), quantity of concrete kerbs (m), quantity of bituminous wearing course (t), quantity of asphalt concrete (t), quantity of pressed concrete slabs (m^2), preparatory works, earthworks, drainage works and works on traffic signalization.

Author	Year	Title	Objectives	Methodology	Conclusions/Comments
Hasan Abu Jamous	2013	Parametric Cost Estimation of Road Projects Using Artificial Neural Networks	Develop artificial neural networks model to estimate the cost at early stage of road projects in Gaza strip using parametric techniques and reduce the percentage error of estimation by identifying the factors that affect the cost of road projects available at early stage.	Correlational	9 factors identified namely project scope, water networks, pavement type (asphalt or interlock), pavement area, sidewalk & island pavement area, length of the road, length of the kerbstones, lighting networks and sewage networks
Muqeem et al.	2011	Construction labour production rates modelling using artificial neural network	Develop a neural network prediction model for predicting labor production rates that takes into account the factors which are in qualitative form	Correlational	Based on the questionnaires returned, 5 factors which were highly significant that were identified were weather (F1), availability of material and equipment (F2), project location (F3), site conditions (F4) and number of workers (F5).
Ministry of Roads Kenya Republic of	2011	Cost Estimation Manual for Road Maintenance Works,	Manual to provide road authorities a scientific index on the approximate price of preventive maintenance, formulate annual work plans, and as an auditing tool for various maintenance works awarded.	Exploratory Interviews and questionnaire surveys	Cost Estimation manual with unit rates on routine maintenance works built up from first principles.
Florida Department of Transportation (FDOT)	2010	Guideline for establishing construction contract duration	To provide guidelines for determining contract time for construction projects	Descriptive	In establishing production rates to be used for determining contract time, an accurate database should be established by using normal historical rates of efficient contractors
Memon et al.	2010	Factors Affecting Construction Cost Performance in Project Management Projects: Case of Mara Large Projects (Malaysia)	Investigate factors that affect cost estimation in Malaysia	Case study	Fluctuation in prices of materials was a major factor in Malaysia
Trombka Aron and Sarah Downey	2008	A Study of County Road Project Cost and Schedule Estimates	Investigate factors that affect cost estimation in Montgomery county, USA	Case study	In Montgomery county, USA, utility relocation was a major factor due to the developed nature of the country.

Author	Year	Title	Objectives	Methodology	Conclusions/Comments
Krzysztof Schabowicz & Bozena Hola	2007	Mathematical-neural model for assessing productivity of earthmoving machinery	Apply artificial neural networks to predict productivity for earthmoving machinery systems, consisting of excavators and haulers	Correlational	5 input factors were used namely: hauler capacity, excavator bucket capacity, road category, number of excavators and number of haulers
Enshassi et al.	2007	Contractors' Perspectives towards Factors Affecting Cost Estimation in Palestine	Investigate factors that affect cost estimation in Palestine	Exploratory/ Interviews and questionnaire surveys	In Palestine, major factors include closure and blockade of borders indicating that security concerns are a major risk for contractors
Mackenzie, N. & Knipe, S.	2006	Research Dilemmas: Paradigms, methods and methodology, Issues in Educational Research,	Expose various approaches undertaken by many writing in the field through a review of research books	Explanatory	Compilation of research terminology for early career researchers adequately defining the role of the paradigm as being paramount to the choice of methodology.
Jiang Y., Wu H.,	2004	Determination of INDOT Highway Construction Production Rates and Estimation of Contract Times	To generate more accurate values of productivity rates and to provide more reliable methods for estimating contract time.	Empirical	Recommends that INDOT use the new production rates to replace the existing values and also update the production rates periodically in the future to reflect the changes in production rates.
Ministry of Works and Supply/ILO/ASIST	2004	Contractor's Handbook For Labour-Based Road Works	To provide guidelines for productivity rates for most of the activities that are carried out on labour-based sites	Descriptive	The paper advises contractors to use the productivity guidelines cautiously. It further encourages them to develop their own set of rates based on their site experience.
Setyawati B.R., Sahirman Sidharta, and Robert C. Creese,	2003	Neural Networks for Cost Estimation	To test the applicability of neural networks for cost estimation in building construction and determine the appropriate architecture in terms of the number of hidden layers, number of hidden nodes, activation function, and number of training data sets upon the model performance.	Explanatory Collaborative/brainstorming	The appropriate structure was one hidden layer, four hidden nodes, one output node, the tangent (tn) activation function, and 60% of the data used for training.

Author	Year	Title	Objectives	Methodology	Conclusions/Comments
Emsley et al.	2002	Data modelling and the application of a neural network approach to the prediction of total construction costs	Development of neural network models of total construction project cost based on recent historical project data	Exploratory Interviews and questionnaire surveys	Initially, 43 input variables were identified, subsequently reduced to 41, as two variables were eliminated (sanitary installations and disposal installations)
Al-Tabtabai et al.	1999	Preliminary cost estimation of highway construction using neural networks	The neural network developed used to estimate the percentage increase in the cost of a typical highway project from a baseline reference estimate.	Explanatory	The developed neural network was integrated easily into Windows-based spreadsheet system assisting in the generation of a preliminary cost estimate. The integration capability allowed the use of trained neural networks for similar construction projects to provide accurate estimates.
Moselhi and Siqueira,	1998	Neural networks for cost estimating of structural steel buildings	Develop an automated cost estimating system for structural steel framing using Neural networks and compare with linear regression	Explanatory	NN out performed linear regression and developed model increased accuracy of prepared estimate and also provided flexibility to management team to respond to market conditions.
Bode, J.	1998	Neural Networks for Cost Estimation	Present results of using neural networks for cost estimation and compare to conventional parametric methods	Explanatory Collaborative/ brainstorming	Neural networks produce better cost predictions than conventional costing methods if a number of conditions hold.
Division of Roads and Transport Technology, CSIR	1998	Standard Specifications for Road and Bridge Works	Method of unit and payment measurement for contract signed on most road projects between employer and contractor in the Zambian Road Sector	Descriptive	This contract is more than 15 years old and should be revised to take into account prevailing conditions. Some pay items are not applicable due to technology transformation.

Author	Year	Title	Objectives	Methodology	Conclusions/Comments
Ayed Amr S	1997	Parametric cost estimating of highway projects using neural networks	To use a non-traditional estimating tool, Neural Networks, to provide an effective cost-data management for highway projects and develop a realistic cost estimating model	Predictive	Neural Networks is a promising tool for use in the initial stages of construction projects when typically only a limited or incomplete data set was available for cost analysis.
Smith, Alice E., and Mason Anthony K.	1997	Cost Estimation Predictive Modeling: Regression Versus Neural Network	Examine the performance, stability and ease of cost estimation modelling using regression versus neural networks to develop cost estimating relationships (CERs).	Explanatory Collaborative/brainstorming	Neural networks have advantages when dealing with data that does not adhere to the generally chosen low order polynomial forms, or data for which there is little a priori knowledge of the appropriate CER to select for regression modeling.
Creese and Li,	1995	Cost estimation of timber bridges using neural networks	To use Neural networks to determine outputs from inputs with varying hidden layers and compare results with linear regression	Predictive	The overall training error decreased as more input variables were accepted to the training, The estimates obtained from the neural networks are better than those obtained from linear regression.
De la Garza, J. and Rouhana. K.	1995	Neural Network versus parameter-based application	Comparison of performance of parametric estimating and neural networks.	Explanatory Collaborative/brainstorming	Findings showed that the neural network technology outperformed the parametric estimating techniques based on regression analysis and presented strong predictive capabilities.
Elinwa AU and Buba SA.	1993	Construction cost factors in Nigeria	Investigate factors that affect cost estimation in Nigeria	Exploratory Interviews and questionnaire surveys	Shortage of materials affect construction cost the most in Nigeria. In addition, the inclusion of corruption as a factor indicated an issue or risk contractors had to deal with in Nigeria.

Author	Year	Title	Objectives	Methodology	Conclusions/Comments
Michael A. Harber	1988	Survey of productivity rates used for highway construction	Analyze the productivity rates used by the FDOT to determine contract duration with respect to highway construction contracts.	Questionnaire	The standard productivity rates for highway construction presented in the report will assist the FDOT in estimating a more predictable project contract duration
Geddes Spence	1960	Estimating for Building and Civil Engineering works 2nd Edition	Compile book of reference on estimating as applied to Building and Civil Engineering works of construction	Explanatory Collaborative/ brainstorming	Provides estimates using built up rates from first principles.

Chapter Three: Research Methodology

3.1 Introduction

Chapter Two presented literature reviewed over the course of this study. It considered various studies conducted in the field of non-parametric cost estimation. Literature revealed that neural networks obtained better results than regression analysis for construction cost estimation (Setyawati et al., 2003). This chapter examines the overall approach to the research process undertaken to achieve the objectives of the study. Various research methods available in the field of cost estimation were examined, and their strengths and limitations highlighted. Methods considered appropriate for this study formed the research typology.

3.2 Research philosophy

Research has been undertaken since time immemorial. Man has always been curious, questioning what he does and trying to solve problems. Pozzo (2004) stated that Aristotle (384 BC–322 BC) is recognized as the inventor of scientific method because of his refined analysis of logical implications contained in demonstrative discourse, which goes beyond natural logic and does not owe anything to the ones who philosophized before him. Research, therefore, evolved as a science with a definition and a methodology. Creswell (2003) defined research as a process of enquiry and investigation; it is systematic, methodical and ethical. Research can help solve practical problems and increase knowledge. Creswell (2003) went on to state that there were two main research paradigms: namely quantitative also known as positivistic, objectivist, scientific, experimentalist or traditionalist; and qualitative referred to as subjectivist, humanistic or interpretative. The philosophical orientation of research is based on a worldview that underlies and informs methodology and methods (Corbin and Strauss, 2008). Table 3.1indicates the comparisons of the two research paradigms on internationally accepted assumptions (Creswell, 2003; and Raddon, 2014).

Table 3.1: Comparison of positivism and interpretivism assumptions of research philosophy

S/No.	Assumption	Quantitative	Qualitative
1.	Ontological (how we understand existence or reality)	Reality is objective and singular, apart from the researcher	Reality is subjective and multiple as seen by participants in a study
2.	Epistemological (how we obtain valid knowledge)	Observable facts. Researcher is independent from that being researched	Researcher interacts with that being researched
3.	Axiological (basis of values)	Value-free and unbiased e.g. Universal principles and facts	Value-laden and biased e.g. culturally and historically situated interpretations
4.	Rhetorical (research language)	Formal, based on set definitions, impersonal voice, use of accepted quantitative words	Informal, evolving decisions, personal voice, accepted qualitative words
5.	Methodological (research process)	Deductive process; cause and effect; static research design - categories isolated before study; context free (independent); generalisations leading to predictions, explanation, and understanding; accurate and reliable through validity and reliability (testing)	Inductive process; mutual simultaneous shaping of factors; emerging design-categories identified during research process; context-bound; patterns and theories developed for understanding; accurate and reliable through verification
6.	Data collection methods	Surveys, questionnaires, random sampling, experimental studies, longitudinal studies, cross-sectional studies	Ethnographic study; in-depth interviews; analytical approaches, case studies, action research, participative enquiry, feminist perspectives, grounded theory
7.	Advantages	• Economical collection of a large amount of data • Clear theoretical focus for the research from the outset • Greater opportunity for the researcher to retain control of the research process • Easily comparable data	• Facilitates understanding of how and why • Enables the researcher to be alive to changes which occur • Good at understanding social processes • Allows for complexity and contextual factors
8.	Disadvantages	• Inflexible – direction often cannot be changed once data collection has started • Weak at understanding social processes • Often does not discover the meanings people attach to social phenomena	• Data collection can be time consuming • Data analysis is challenging and can be complex • Researcher has to live with the uncertainty that clear patterns may not emerge • Generally perceived as less credible by 'non-researchers'

(After Creswell, 2003; and Raddon, 2014).

Both paradigms have their place in research. Both approaches have their pros and cons. Modern complex, interdisciplinary and dynamic research requires the use of both methods to provide superior research results. Collaboration among researchers entails a solid understanding of multiple methods used by other scholars. Johnson and Onwuegbuzie (2004) defined mixed methods research as the class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study. They further went to describe it as the "third wave" or third research movement that moves past the paradigm wars by offering a logical and practical alternative. Wright (1995) argued that by combining qualitative with quantitative methods, the resulting research would be much more meaningful and would have a greater probability of being valid and actually measuring what it purported to measure. Cohen et al. (2000) stated that the issue was not which approach was adopted over the other but rather making use of the most valuable feature of each type. For example, adding qualitative interviews to experiments as a manipulation check and perhaps as a way to discuss directly the issues under investigation and tap into participants' perspectives and meanings would help avoid some potential problems with the experimental method (Johnson and Onwuegbuzie, 2004). To be able to use the mixed methods or combined method approach, a solid understanding of the various types of research, their data collection methods, analysis and reporting was essential.

3.3 Methods of research

Ghosh (2011) stated that sciences as a whole lay greater emphasis on methods than results. A method is a way of approaching a problem. If research takes a wrong approach, the systematic knowledge or the truth will not be uncovered. Methodology therefore stands for the correct arrangement of thoughts either for the discovery or the exposition of truth (Ghosh, 2011). Whether the research is inductive or deductive, a correct methodology is required for arriving at a correct or an exact knowledge which science endeavours to establish. Therefore, depending on the research problem, a proper methodology has to be framed. Different available methodologies are discussed below.

3.3.1 Exploratory research

Exploratory research is conducted when a researcher is exploring new insights about a phenomenon. Though this is typically qualitative research, the approach is to determine whether or not a phenomenon exists and to gain familiarity with such a phenomenon rather than compare it with other phenomena (Welman and Kruger, 2001). The aim is to look for patterns, hypotheses or ideas that can be tested and form a basis for further research. Typical research techniques would include case studies, observation and reviews of previous related studies and data (Neville, 2007). Examples include feasibility or pilot studies. A major limitation of this research approach is that there are few or no earlier studies to which references can be made for information.

3.3.2 Descriptive research

The purpose of descriptive research is to describe an existing phenomenon (Welman and Kruger, 2001). Descriptive research is used to identify and obtain information on the characteristics of a particular issue. It may describe the relationship between variables without trying to explain it. The data collected is often quantitative and statistical techniques are usually used to summarise the information. This is in contrast with Walliman (2001) who indicates that this is qualitative research. However, Ghosh (2011) states that this method is concerned with the interpretation of data.

3.3.3 Explanatory research

Explanatory or analytical research goes beyond merely describing characteristics. Findings are analysed and explained to establish causes and effects. On the basis of the results of a study, a researcher would attempt to explain the findings (Welman and Kruger, 2001). Thus, analytical research aims to explain the relationship among variables. An important feature of this type of research is in locating and identifying the different factors (or variables) involved (Neville, 2007). Explanatory research is valuable for understanding questions of efficacy but is limited when it comes to establish whether a particular action will yield desired results when carried out in the real world.

3.3.4 Predictive research

Predictive research goes beyond the explanatory approach by forecasting the likelihood of a similar situation occurring elsewhere. The researcher, on the basis of findings, may wish to predict the phenomenon occurring again (Welman and Kruger, 2001). Neville (2007) stated that the aim of predictive research was to speculate intelligently on future possibilities, based on close analysis of available evidence of cause and effect.

3.3.5 Classification

Ghosh (2011) described classification as a scientific method used to extend the horizon of knowledge. To classify is to group things together, based on a particular trait or similarity. Classification is the first method in science to determine objective relations among things. Ghosh (2011) further stated that classification is similar to explanation. Classification aids memory, as it is easier to remember similarities or differences. Scientific classification has its limits in that it proceeds from less general to more general. It becomes a challenge to things that cannot be defined as they cannot be classified. Cases that have similarities with two different classes cannot be scientifically classified.

In this study classification was used in as far as recommending a cost estimate classification system. This was critical to ensure that it was easy to classify cost estimates from the model in terms of accuracy.

3.3.6 Experimental research

Experimentation is the most scientifically sophisticated research method (Sidhu, 2006). Generally, research problems are concerned with relationships between variables. To determine this relationship, experimental and non-experimental methods are used. Brewerton and Millward (2001) described experimental research as the manipulation of independent variables under highly controlled conditions in order to observe any changes in dependant variables. Therefore, the researcher would be trying to determine the cause-effect relationships. Different types of experimental design include (Walliman, 2001):

a) pre experimental: unreliable assumptions are made despite the lack of control over variables;
b) true experimental: rigorous check of the identical nature of groups before testing the influence of a variable on a sample of them under controlled circumstances; and
c) quasi experimental: not all conditions of true experimental design can be fulfilled but the shortcomings are identified.

However, a major limitation is that this method is usually done in the laboratory, allowing for highly controlled settings. These artificial conditions may not reflect the real world and what really happens out there.

3.3.7 Correlational research

Correlational or non-experimental research attempts to explore the relationship between at least two variables within a given environment (Brewerton and Millward, 2001). Changes to one variable are accompanied or associated with changes to the other, but that one change is not necessarily the cause of the other. For instance, a causal relationship between variables X and Y also implies a correlational relationship between them. However, a correlational relationship between variables X and Y is not necessarily an indication of a causal relationship between them (Welman and Kruger, 2001).

In this study correlational research was employed in the investigation of factors relevant to the Zambian road sector.

3.3.8 Longitudinal Studies

These are studies over an extended period to observe the effect that time has on the situation under observation and to collect primary data of these changes. Longitudinal studies are often conducted over several years. However, it is possible to base short time scale research on primary data collected in longitudinal studies (Neville, 2007).

3.3.9 Historical research

Leming (1997) stated that though most sociologists do not acknowledge historical research as a type of methodological approach, it consists of content analysis and statistical evaluation of data originally collected for some other purpose. Sidhu (2006) states that historical research is one of the most difficult types of investigations to conduct adequately. He described historical research as the application of a scientific method of inquiry to historical problems. There are three approaches to historical research through reference of (Sidhu, 2006): historical facts in support of new concepts to be developed; historical subjects such as biographies of great men, monographs of places and sketches of thoughts, trends and ideas; and historical technique conducted on the basis of historical records and documents. On the use of documents, the more recent a document to the period under investigation the more believable it is (Ghosh, 2011). Advantages include appropriateness for trend analysis and cost-effectiveness when compared to longitudinal studies. Major disadvantages include interpretation biasness and weak internal validity due to lack of control over external variables.

3.3.10 Cross-sectional studies

Cross-sectional studies involve a close analysis of a situation at a particular point in time to give a ‘snap-shot’ result (Neville, 2007). They are simple in design and are suitable when time or resources for more extended research such as longitudinal studies are limited. Cross-sectional studies are appropriate when finding out the prevalence of a phenomenon, situation, problem, attitude or issue by taking a cross section of the population (Kumar, 2005).

3.3.11 Evaluation research

Walliman (2001) describes evaluation research as a descriptive type of research designed to deal with complex social issues. It is referred to as a fourth generation research method that is closely related to, but distinguishable from more traditional social research. The aim of this method is to provide feedback to stakeholders. The relationship between an evaluation and its impact is not a simple one as studies that seem critical sometimes fail to influence short-term decisions, and studies that initially seem to have no influence can have a delayed impact when more congenial conditions arise (Trochim, 2006). Trochim (2006) goes on to state that despite this, there was broad consensus that the major goal of evaluation should be to influence decision-making or policy formulation through the provision of empirically-driven feedback.

3.3.12 Action research

O'Brien (2001) stated that action research is known by many other names, such as participatory research, collaborative inquiry, emancipatory research, action learning, and contextual action research. He further explained that what separates this type of research from general professional practices, consulting, or daily problem-solving is the emphasis on scientific study, where the researcher studies the problem systematically and ensures the intervention is informed by theoretical considerations. The researcher spends time on refining the methodological tools to suit the exigencies of the situation, and on collecting, analyzing, and presenting data on an ongoing, cyclical basis. In addition, the research takes place in real-world situations, and aims to solve real problems. Finally, the initiating researcher, unlike in other disciplines, makes no attempt to remain objective, but openly acknowledges their bias to the other participants. Walliman (2001) calls action research as an “on the spot” procedure designed to deal with a specific problem evident in a particular situation where no attempt is made to separate a particular feature of the problem from its context in order to study it in isolation. One disadvantage is that it cannot fulfil the scientific requirement of generalisability as it has little or no control over independent variables.

3.3.13 Ethnography

This form of research evolved from anthropology and the close study of societies. Ethnography involves participant observation, where the researcher becomes a participant member of the group or situation being observed. The aim is to experience first-hand the situation being studied. The researcher shares the same experiences as the subjects. Participant observation can be overt where everyone knows it is happening or covert where those being observed are unaware (Neville, 2007).

3.3.14 Feminist research

Research, from a feminist perspective, focuses on knowledge grounded in female experiences and is of benefit to everyone, but particularly women (Neville, 2007). Feminist research perspectives have a number of common starting points. First, that women and their contributions to social and cultural life have been marginalized and that this is reflected in past research practice. Second, that men and male perspectives or norms have dominated previous research. And third, that gender, as a significant factor in understanding the world, has been absent from understandings and interpretations of social phenomena, in favour of other categories such as social class. Feminist perspectives draw attention therefore, to how women or women's concerns in previous research have been excluded, ignored or relegated to the periphery (Neville, 2007).

3.3.15 Grounded theory

Grounded theory qualifies as qualitative research. It is an approach that emphasises the generation of theory from data. Theory is generated from observations made, rather than being decided before the study. The aim of grounded theory is then to approach research with no preconceived ideas about what might be discovered or learnt. While collecting data, the researcher generates certain insights and introspection from the data to form certain generalisations, hypotheses and concepts (Ghosh, 2011).

3.3.16 Case study

The term case study pertains to the fact that a limited number of units of analysis such as an individual, a group or an institution are studied intensively (Welman and Kruger, 2001). This allows the researcher to explore and understand problems, issues and relationships. When an institution or group is investigated, the researcher is conducting fieldwork. Welman and Kruger (2001) disclosed that whichever technique is used to collect data, the concern is not merely to describe what is being observed, but to search in an inductive fashion for recurring patterns and consistent regularities. Therefore, because this method is a non-experimental, descriptive type of study and not an explanatory one, conclusions about cause-effect relationships cannot be drawn.

Advantages of the case study method include the capture of rich information from which potentially useful hypotheses can be generated. Case studies can be used as examples to illustrate problems or show benefits of particular practices resulting in making practical improvements to specific situations (Welman and Kruger, 2001). They provide more comprehensive examination of a particular situation than any other research design. Because case studies draw from actual experiences and practices, they are strong on reality, making them useful as a consultancy.

On the other hand, the case study approach raises concern because it does not allow the researcher to generalise from one case. The case would need to be contextualised and carefully described for others to consider its usefulness in other contexts and examples (Wisker, 2001). Information collected from a case study may be retrospective as some studies take long. In this sense, it is historical and is therefore subject to the problems inherent to memory. Sometimes, impartiality is lost and subjectivity becomes an issue.

The research design of the study was determined after considering the various methods in relation to the research problem.

3.4 Research design

Research design is a plan of the proposed study (Ghosh 2011). Brewerton and Millward (2001) noted that different research approaches use different techniques or methods because they have different aims. When reviewing literature, the researcher is expected to identify the research approach to be employed. Welman and Kruger (2001) described research design as the plan according to which research participants or subjects are obtained and how information collected from them assists with reaching conclusions about the research problem. Figure 3.1 shows the research approaches that influenced the study. It shows the typology of the research study indicated by the black dotted line. Mackenzie and Knipe (2006) referred to this as a research journey.

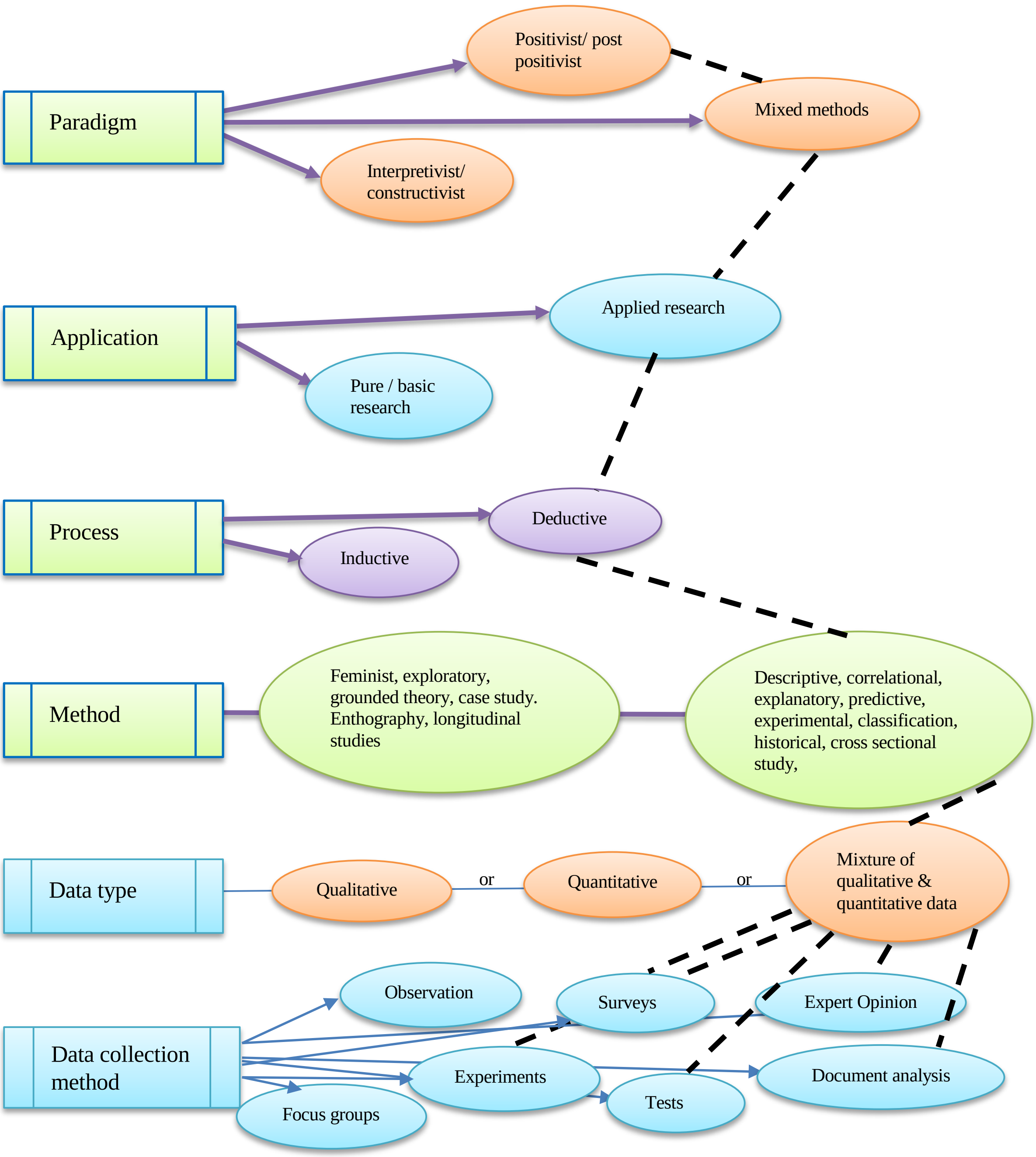


Figure 3.1: Research typology
(After Mackenzie and Knipe, 2006)

3.4.1 Research paradigm

Even though this study was skewed towards a positivist approach, it adopted a mixed or combined approach to benefit from the significance of each approach. The ontological, epistemological and axiological assumptions of the research were quantitative but the study utilised qualitative rhetorical method that enabled the research to be alive to changes through evolving decisions using accepted qualitative words. This allowed for complexity and contextual factors to be effectively analysed.

3.4.2 Application

In terms of its application, this study was categorised as applied research as opposed to pure research. Kumar (2005) stated that pure research involved developing and testing theories and hypotheses that were intellectually challenging but may or may not have practical application though the knowledge produced added to the existing body of knowledge in the particular field. On the other hand applied research is carried out to solve specific, practical questions or to understand a phenomenon. In certain instances, applied research is confused with action research. Sidhu (2006) stated that the difference is that applied research is carried out by experts on a larger sample resulting into more universally applicable findings against action research which is primarily conducted on an immediately available small sample in order to solve the immediate problems of the small group. Most applied research culminates into research models but there is no common agreement on the classification of those models. For the purpose of illustration, five categories of research models and their variants are outlined (University of Southampton, 2014):

a) physical models are physical objects shaped to look like the represented phenomenon, usually built to scale;
b) theoretical models generally consist of a set of assumptions about some concept or system; are often formulated, developed and named on the basis of an analogy between the object, or system that it describes and some other object or different system; and they are considered an approximation that is useful for certain purposes;
c) mathematical models refer to the use of mathematical equations to depict relationships between variables, or the behaviour of persons, groups, communities, cultural groups or nations. It is an abstract model that uses mathematical language to describe the behaviour of a system;

d) mechanical or computer models tend to use concepts from the natural sciences, particularly physics, to provide analogues for social behaviour. They are often an extension of mathematical models. Many computer-simulation models have shown how a research problem can be investigated through sequences of experiments; and
e) symbolic interactionist models used to untangle meanings that individuals give to symbols that they use, or encounter. They are generally simulation models, that is they are based on artificial or contrived situations, or structured concepts that correspond to real situations. They are characterised by symbols, change, interaction and empiricism and are often used to examine human interaction in social settings.

For this study, the application was practical in that a unit cost model was developed for use as a planning or estimation tool. The model developed could be described as a mathematical model as it utilised mathematical equations to depict relationships between variables whose output was a computer based model.

3.4.3 Process

Ghosh (2011) described deduction as a process of drawing generalisations from universal to particular through a process of reasoning on the basis of certain assumptions which are either self-evident or based on observation. On the other hand, induction is a process of reasoning whereby universal generalisations are arrived at from particular facts. A major merit of deduction is that the method results in accurate and precise generalisation because of the use of logic and mathematical tools of analysis. The distinction between inductive and deductive research are shown in Figure 3.2.

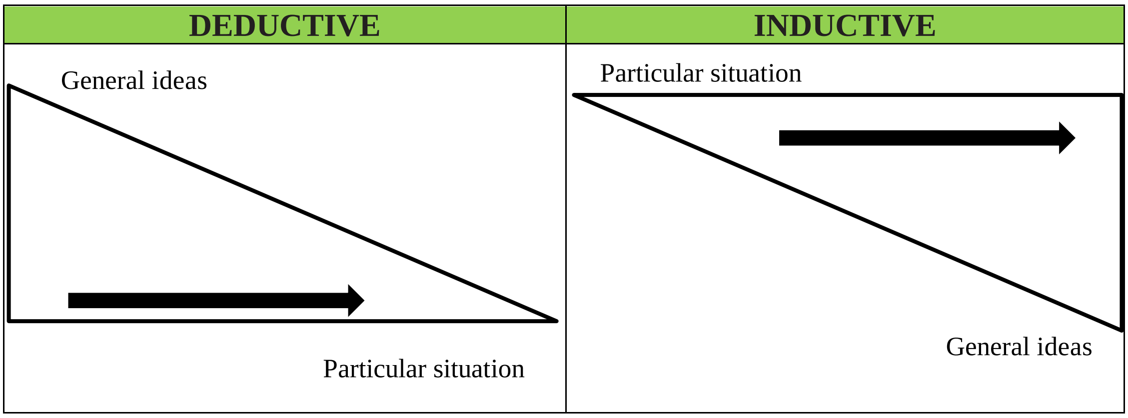


Figure 3.2: Distinction between inductive and deductive research
(after Neville, 2007)

The research study was clearly deductive. From literature review, various calculations and assumptions regarding production of unit cost for road-works were studied. In particular, infrastructure diagnostic systems in high, middle and low income countries were examined. General labour and plant productivity indices were studied. Material specifications and general road construction procedures were obtained from Southern Africa Transport and Communications Commission (SATCC) Design Standards and Specifications. These general standards and norms were then utilised to formulate a description of the Zambian construction industry in terms of labour and plant productivity index and establish specific factors that affect construction unit rates in Zambia.

3.4.4 Methods

It is common for research to employ various methods. Kumar (2005) stated that in practice, most studies are a combination of descriptive, correlational and explanatory. Indeed this research study incorporated all three methods. The study was **descriptive** in that it provided a description of the Zambian construction industry (ZCI). It described its labour and plant efficiencies. It stated infrastructure material quality and availability. In addition, detailed estimating can be achieved only when a product is well defined and understood. Therefore, road construction was described as pertained to ZCI. In general, the study described what was prevalent in ZCI. As stated by Ghosh (2011), the description was concerned with the interpretation of data. The **correlational** aspect of the study was derived from examining the number of variables and establishment of functional relationships between changes in cost and the factors upon which the cost depends. In addition, cost estimation relationships were determined and used in a mathematical function. Apart from determining the functional relationship of the cost variables or factors, the relationship had to be explained. This aspect employed **explanatory** research.

Other dimensions of the study incorporated techniques of predictive research. The very nature of estimation begets forecasting. Forecasting is enshrined in predictive research. The study was in whole about the prediction of costs. The study involved intelligent speculation on future possibilities, based on close analysis of available evidence of cause and effect. The study employed detailed unit cost estimation, based on plant, labour, materials and overhead costs to predict expected rates of work for roadwork tasks. Some aspects of comparative research methodology were employed as the unit cost estimates had to be comparable to the Southern African Development Community (SADC) region. Finally, the study incorporated historical research in that historical data had to be collected. The historical technique approach was conducted on the basis of historical records and documents. It goes without saying that survey of related studies may be interpreted as a subcategory of the historical technique approach. Survey of related studies draws on accumulated and recorded knowledge of the past.

In short, though the research employed various methods to enrich the study, it can be generally categorised as a correlational study. It strove to use the merits of each method blended to produce a meaningful and practical solution to the research problem.

3.4.5 Data types

Research involves the collection of data. Data types are either qualitative, usually words or text, or quantitative like numbers, statistics or financials. Quantitative data may be presented in graphical form. Although the data for the study was mostly quantitative, a mixture of qualitative and quantitative data was collected.

3.4.6 Data collection methods

The data collection method depends on whether the data to be collected is primary or secondary. Primary data is original in that it is information which has never been collected before. Secondary data is information already put together by someone else but reused in a different way by the researcher (Blaxter et al., 2001).

i. Secondary data

Secondary data is generally collected through survey of related studies or literature review. Sidhu (2006) described survey of related studies as locating, studying and evaluating reports of relevant researches, study of published articles, going through related portions of encyclopaedias and research abstracts, study of pertinent pages out of comprehensive books on the subject and going through related manuscripts if any. Secondary data is the foundation for any study and avoids duplication. Secondary sources can further be categorised as paper-based sources such as books, journals, periodicals, abstracts, indexes, directories, research reports, conference papers, market reports, annual reports, internal records of organisations, newspapers and magazines and electronic sources such as CD-ROMs accompanying books, e-books, on-line databases, social networks, blogs, websites, e-mail, movie clips (you-tube) podcast, webinars and wikis.

The amount of electronic information is enormous and its accessibility makes it an attractive source of research. A drawback of internet information is that it is not permanent. Websites are continually updated and information accessed from a particular website may not be available years later for reference. Authority of a particular source of information becomes an issue because the internet is a public domain resource. Reliability of a website and determining the age of the material is difficult. A site maintained by an academic or government institution is probably more credible than one published by a private user (Brewerton and Millward, 2001). Some of the secondary sources employed in the study included:

a) Research journal and periodicals

These are still the most up to date sources of latest information in any field of study. Journals publish original work that addresses cutting edge issues related to a particular field of study. Journals are respected international refereed publications issued periodically. The articles published are of high quality undergoing a rigorous peer review process before publication. These articles are scholarly in nature and are considered serious, truthful and correct. The articles are authored by professionals in their respective fields thus providing a forum for disseminating knowledge and exchanging ideas between industry and academia. The journals most referred to in this study were the Cost Engineering Journal and the International Journal of Neural Networks.

b) Books

There are a variety of books available today. Wilkinson (2005) classified books as text, research and edited books. He described text books as being based upon the expertise of the author, containing some reference to research and the experiences of the writer whilst research books report on an area specifically investigated for the purposes of the text making them more focused and exploratory than text books. Lastly, Wilkinson (2005) described edited books as consisting of a collection of pieces or papers written by a variety of authors drawn together by a common theme or issue. Merits of paper books include handwritten annotation, highlighting with coloured markers, underlining and bookmarking. Unlike the internet the reliability, status of the author, age of the material and details of sources and references is easily verifiable.

The study used books because they are authoritative as they have undergone some form of peer review process. Books are permanent and all books used in the study as references can easily be traced by other researchers.

c) Reports

Other paper based sources used in the study were reports. Reports are usually produced by institutions or organizations of different kinds, including employers, representative associations, political parties, trade unions, voluntary bodies, community groups, central and local governments and international bodies (Blaxter et al., 2001). They are a good source of information because they contain information unique to the institution or organization. A report includes information such as the organization’s operations, its performance and its future plans. In Zambia, reports by institutions or organizations are usually produced annually and are commonly referred to as annual reports.

As government is the major investor in public roads, this study used reports from the Road Development Agency (RDA), a statutory body regulating the road sector and National Road Fund Agency (NRFA) a government road financing institution in Zambia.

d) Newspapers

Newspapers fall under the popular media category. Newspapers can be daily or weekly. The role of newspapers is to inform the public of events of importance and appropriate interest in a manner that is accurate and comprehensive and it is up to the public to make judgements on the issues. Generally, newspapers are loosely divided into national news, international news, advertisements, public opinion, sports news and editorial columns. Apart from reporting events, newspapers sometimes have special features articles which are in-depth reports of a particular subject. Editorial columns are usually critical reviews focused on a particular subject highlighted by the newspaper. Newspapers are fast gaining recognition as a valuable tool for public policy reform. Journalists are accountable to the public for their reports and the public have a right to voice its grievances against the media. A major advantage of newspapers is that the information is current. It is easy to read newspapers from other countries over the internet. Archives of the newspapers are kept and it is relatively simple to search for a previous event. Newspapers have pitfalls which include subjectivity and inaccuracy of the information released resulting in public apologies. The review process is less rigid than other forms of literature previously discussed.

The study itself envelops political and economic effects on road-works. The study therefore used newspapers as part of its secondary source because this is one area where political concerns are highlighted. Public concerns or opinions regarding government policies in the road sector were included from excerpts from newspapers.

e) Electronic sources

The advent of virtual libraries has brought proficiency in the review of literature such as the ability to: locate sources directly; browse through multiple sources quickly; and collect relevant material. Internet based information was used to complement the scarcity of books available on cost estimation and neural networks in Zambia. Because of the global nature of information, the data obtained was also used to compare trends in the SADC countries.

ii. Primary data

Primary survey is conducted in order to acquire directly the relevant facts (Ghosh, 2011). A primary source is the written or oral account of a direct witness of, or a participant in an event or an audio tape, videotape or photographic recording of it (Welman and Kruger, 2001). In other words, primary research is an investigation where data is collected directly using methods such as questionnaires or interviews. Collection of data using such methods may be referred to as 'normative–survey'. Survey indicates gathering of data whilst normative indicates the purpose of the survey which is usually ascertaining the normal or typical condition or the practice (Sidhu, 2006). Normative survey method gathers data from relatively large samples and is concerned with generalised statistics of a representative sample and not with individual characteristics. Normative survey techniques include: questionnaire inquiries, interview studies and observational studies.

a) Expert opinion

Expert opinion may be gathered using various techniques. The most common technique is through interviews.

i) Interviews

Interviews can be described as a kind of verbal technique for obtaining data (Ghosh, 2011). Interviews are a two way method which permits an exchange of ideas and information (Sidhu, 2006). Interviews provide a lot of information from a small number of people and are useful when the researcher requires an expert or knowledgeable opinion on a subject. Interviews can take a variety of forms depending on the type of data required to address the research question being asked, as well as on the availability of resources (Brewerton and Millward, 2001). There are three types of interviews namely structured, unstructured and semi structured.

Structured interviews involve having a complete set of well-defined questions. Sometimes even the alternative questions are fixed and the interviewer has to follow the written format. This method ensures a quick interview and easy comparison of responses. The interviewer is there to clarify any confusion the questions may pose. Disadvantages include restriction of the interviewee and of further research and investigation into the area of interest.

Unstructured interviews provide the interviewer complete freedom to ask any question in the area of interest to the interviewee, allowing for questions to change depending on how the interview proceeds. The interviewee's responses are not restricted and usually provide in-depth data gained from experience but comparison, quantification and analysis of responses becomes a daunting task.

Semi structured interviews incorporate elements of both quantifiable, fixed choice responses and the facility to explore and probe in more depth certain areas of interest (Brewerton and Millward, 2001). Therefore, this type of interview has both advantages and weaknesses of interview methods discussed earlier. While being easy to compare, quantify and analyse, the method also allows for exploration in the area of interest resulting in in-depth information being provided.

Interviews can also be classified according to the number of people being interviewed or number of interviewers.

a) Individual or Group interviews

The number of persons participating in an interview may be one or many. Group interviews entail bringing a number of persons to explore a problem. This can provide a wide range of information or varied viewpoints (Sidhu, 2006). But interviewees may refrain from expressing some points before a group while one person may dominate the discussion.

b) Single or panel of interviewers

The number of interviewers may be one or many. A panel of interviewers is appropriate when the field of study is wide and varied. The panel may consist of different experts in the areas to be covered.

Advantages of interviews in general include the interviewer being in control and able to assist if there is a problem. The response rate is good, complete and immediate. Depending on the situation, recording equipment or props can be used. The one-on-one session presents the interviewer an opportunity to investigate motives and feelings and assess the characteristics of the respondent by their tone of voice, facial expression and hesitation. In contrast, disadvantages of interviews include the need to set up appointments for interviews, geographical limitations, high expenses and time consuming. Some questions, if personal, could cause embarrassment and sometimes respondents could be biased by trying to please, impress, create a false personal image, or by ending the interview quickly.

Telephone interviews are an alternative form of interview to the personal, face-to-face engagements. These were not used in this study because of the question of authenticity such as verification of the other person on the line.

ii) Delphi technique versus nominal group technique

Two popular structured communication techniques are the Delphi and the Nominal Group Technique. These techniques can be seen as modified group or panel interviews. Yousuf (2007) states that the Delphi technique is a method pertaining to the utilisation of expert opinions. Essential components of the Delphi technique include the communication process, a group of experts, and essential feedback. He further states that the minimum number of participants to ensure a good group performance is dependent on the study design. The outcome of a Delphi sequence is nothing but opinion, whereas the panel viewpoints are summarized statistically rather than in terms of a majority vote (Yousuf, 2007). The Nominal Group technique is a structured face-to-face group session with the purpose of achieving group consensus and action planning on a chosen topic (Varga-Atkins et al., 2011). Kratz (1992) found that Nominal Group Technique was superior to the Delphi Technique from a social-emotional satisfaction of the committee members, but that there was no difference between the two processes with regard to the quality of the decisions reached.

In this study the Delphi technique was adapted to meet study objectives. Al-Tabtabai et al. (1999) stated that effective construction project estimating is heavily dependent on experience. Therefore, ten experts were selected based on their experience, qualifications, and interest shown in the study to verify major cost parameters in highway construction in Zambia. The cost parameters deduced from expert opinion were then used in the model development. This methodology was appropriate because in cost estimation choosing cost drivers is the most important step since the model's accuracy is based upon selecting the relevant and appropriate cost drivers (Blocher et al., 2008).

b) Questionnaires

Ghosh (2011) describes a questionnaire method as one in which a number of printed questions is used for collecting data. Questionnaires are used to collect information from respondents who are scattered in a vast area. As research instruments, most questionnaires are structured. When constructing questionnaires, thought has to be given between open-ended questions where the respondents can formulate their own responses or closed-ended questions where respondents are restricted to categorised responses. Open-ended questionnaires are advantageous where new facts are being sought. Open-ended questions may be more suitable for respondents who are highly educated but may be more difficult to score and compare because of the varying responses. Closed-ended questions may be easier to score but may generate incomplete results because the restrictive responses may not be adequate to their unique situation.

Mixed questionnaires consisting of both open and closed-ended questions are used in social research.

In general, questionnaires are considered advantageous because they are relatively cheap and they can cover a wide geographic area through hand delivery, postage, e-mail or website survey. In addition, participants have time to consider responses thus avoiding embarrassment on the part of the respondent as there is no interviewer bias. Some respondents prefer anonymity which questionnaires can provide. Because no prior arrangements are needed, questionnaires are appropriate for respondents in busy industries.

A disadvantage of questionnaires is that they assume no literacy problems. Certain questions may require an explanation and in the absence of the researcher, the respondent may not answer the question. Incomplete questionnaires may impact the findings negatively and the researcher would have to redesign the research instruments. Another disadvantage is that most questionnaires require a return deadline and there could be a time delay whilst waiting for responses to be returned.

The study employed questionnaires to gather primary data from the construction industry regarding cost parameters such as labour and plant productivity levels. Obtaining an appointment for the targeted population sample would have proved difficult but the use of questionnaires addressed this concern since no prior arrangements were needed. The RDA is present in all ten provinces of Zambia thus covering a wide geographical area. It was ideal to distribute some of the questionnaires via email and through the RDA website.

c) Observation

Observation involves taking note and recording in as objective a way as possible, target events and occurrences, using whatever unit and level of analysis required for the achievement of research objectives. Brewerton and Millward (2001) emphasized that observation is a highly skilled activity which should not be considered lightly. Observation is a more natural way of gathering data (Sidhu, 2006). Observation can be disguised or undisguised. In disguised observation, participants behave naturally because they are unaware that they are being observed. In undisguised observation, participants are aware that they are being observed. The problem with this is that people behave differently when being observed. There are two types of observational activity namely, participant and non-participant (Brewerton and Millward, 2001).

i) Participant observation

In participant observation, the researcher becomes part of the participants. This method is usually unstructured as it monitors all aspects of the phenomenon that seem relevant. The research problem is yet to be formulated precisely and flexibility is needed in the observation to identify key components of the problem. Participant observation has its roots in ethnographic studies, the study of man and races where the researcher would live in a tribal village, attempting to understand the customs and practices of that culture.

ii) Non-participant observation

In this method, the researcher observes from a distance, the interaction processes as the research problem is clearly defined and the information needed is specified. This makes the observation structured where the activity is guided by a checklist.

Generally, the observer merely records what takes place. Mechanical devices such as video recorders and closed circuit television can be used to record what is being observed. One advantage of the observation method is that information is first hand and beneficial to group dynamics using it to identify weaknesses and strengths within a group. The findings are then used as a basis for intervention design.

A major pitfall of observation study is that one cannot record everything. Therefore, the researcher’s interest of observation has to be clarified. Observation study requires skill as in the use of mechanical devices and is time consuming. In non-participant study, the event being monitored might not occur during the allocated time. In all the different types of observation, the potential for bias is high. The validity and reliability of the interpretation of the findings raises concern as there is scope for alternative interpretations. Therefore, observation findings should be treated as hypotheses to be tested rather than as conclusive findings.

The observation method was not selected as it was considered inappropriate for this study.

d) Diaries

Diaries are a way of gathering information about the way individuals or organisations spend their time on professional activities. They can help to capture events that would otherwise disappear from memory (Wisker, 2001). It is common to keep site dairies on construction sites. Site diaries are a daily record of what takes place on site and are not a reflective analytical piece. Generally site diaries would have records of:

i) anyone who goes to the site such as client, consultants, workers and visitors;
ii) any instructions given on site;
iii) work done on that particular day for instance, an entry for carpentry works would state: 4 no. doors fixed to first floor;
iv) plant or machinery used each day noting the fuel and oil consumed;
v) building materials issued daily;
vi) materials tested or opened up for inspection; and
vii) any events occurring on site such as reports of accidents or near accidents, thefts, damages, penalties and absenteeism.

Diaries are kept by the contractor but can be inspected by employers and their representatives. Site dairies are not part of contract documents but may be used as a preliminary or basis for intensive interviewing. With pictures added, dairies become useful in the event of any substantial changes to the scope of works for whatever reason that may cause delays and additional costs, any serious accident, natural disaster or claims by third parties. Additionally, they can help to protect or minimize liability of a client, developer, contractor and the relevant authorities against blame and possible financial claims by assisting in the identification of the parties responsible for the defects and deficiencies in the works. By their nature, site dairies are difficult to find as they do not form part of the contract documents and are not kept after a project is completed but can be a good source of labour and plant utilisation information. Site diaries are considered as primary source as they are unique to a particular project and present a written description of what happened at the time. Site diaries can be used as a contemporaneous record of events. In the same vein, site minutes are a good source of project information.

In this study, where in doubt, site diaries and minutes were used to confirm fuel and oil consumption of some plant or machinery.

3.5 Sampling

In research methodology, the researcher must know which group of participants would provide the most accurate and appropriate data for the study. The research participants come from a population. The population is the study object which may be individuals, groups, organisations, human products and events or the conditions to which they are exposed (Welman and Kruger, 2001). It is impossible to include all members of the population hence researchers depend on data obtained from a sample of the population. A sample is a small proportion of a population selected for observation and analysis while sampling is the process of selecting a sample from the population (Sidhu, 2006). There are a wide variety of sampling strategies available for use. These can be classified in two groups, probability and non-probability sampling (Blaxter et al., 2001).

3.5.1 Probability sampling

In probability sampling, every person or object in the population of interest has the same chance of being selected for the study. Though this might sound simple, the actual methods of probability sampling are complex. One advantage of probability sampling is the researcher being able to estimate the sampling error. Probability sampling strategies include (Blaxter et al., 2001):

a) simple random sampling is selection at random where every member of the sample has an equal probability of being selected. It provided an unbiased cross section of the population;
b) systematic sampling involves selecting every nth case when the sample is listed. It is also known as sampling by regular intervals or sampling by fixed intervals (Sidhu, 2006);
c) stratified sampling is sampling within groups of the population. Stratification introduces a secondary element of control as a means of increasing precision and representativeness. Stratified sampling can be proportionate where the number of units drawn are proportionate, or disproportionate where the units drawn from each strata is independent of the size or stratified weight sampling where equal number

of units are drawn from each stratum and weighted according to the size of the stratum;

d) cluster sampling is the design in which the unit of sampling consists of multiple sampling. It is surveying whole clusters of the population sampled at random and is sometimes known as area sampling; and
e) stage sampling – sampling clusters sampled at random.

3.5.2 Non-probability sampling

Non-probability sampling may be used where the researcher lacks a sampling frame for the population in question or where a probabilistic approach is judged not to be necessary (Blaxter et al., 2001). Non-probability sampling may be broken down as follows:

a) convenience sampling is sampling those most convenient to the researcher. Though this method might not be scientific, quite a number of samples are of this type (Sidhu, 2006);
b) voluntary sampling is where the sample is self-selected and not actually selected by the investigator;
c) quota sampling is convenience sampling within groups of the population. The number to be selected from each group is known as a quota;
d) purposive sampling involves hand picking supposedly typical or interesting cases. It is ideal when there is a specific objective;
e) dimensional sampling or multi-dimensional quota sampling; and
f) snowball sampling which involves building up a sample through informants.

Some advantages of non-probability sampling include ability to capture a wide range of facets. Selection is deliberate allowing the researcher to select with prior design and purpose. This type of sampling is convenient, economical and is beneficial to pilot studies. Pitfalls include higher subjectivity and bias compared to probability sampling thus distorting findings.

3.6 Study methodology

The emphasis of the research was based on model development. Therefore, the methodology focused on the steps involved in developing a UCEM as shown in Figure 3.3.

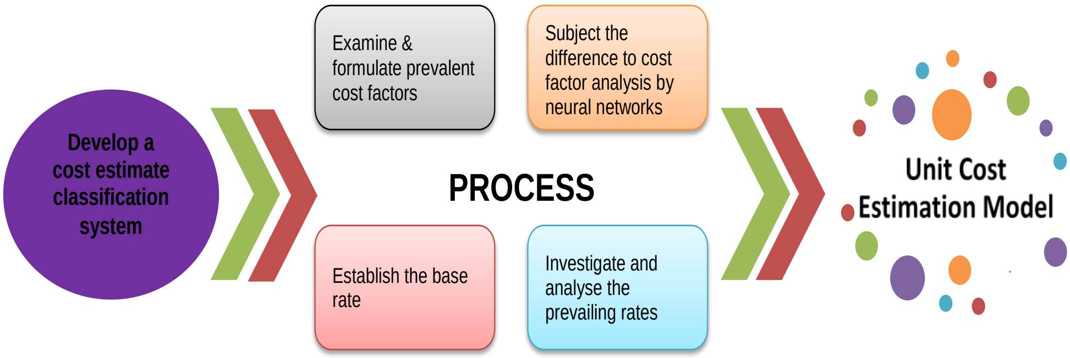


Figure 3.3: Unit cost estimation model development process

3.6.1 Cost estimate classification

It was critical to recommend a cost estimate classification system to benefit from the proposed UCEM. A cost estimate classification system also provides a basis for projects that are shelved at this stage. In the Zambian road sector there are existing undocumented protocols that are broadly understood in terms of types of estimates and their accuracy. The classification guideline is required to avoid misinterpretation of the quality and value of the information available to prepare cost estimates, the various methods employed during the estimating process, the accuracy level expected from estimates, and the level of risk associated with estimates.

3.6.2 Establishment of base rate

The unit rate activities are based on the standard Bills of Quantities template used. The item descriptions are based on the Southern Africa Transport and Communications Commission (SATCC) Standard Specifications for Road and Bridge Works – September 1998 (Re-printed July 2001). The unit rates are further organized into the six main SATCC categories namely: General; Drainage; Earthworks and Pavement Layers of Gravel or Crushed Stone; Asphalt Pavements and Seals; Ancillary Works; and Structures. Expected outputs of various types of civil engineering operations and their listed man hours were obtained and used in formulating unit rates from first principles.

3.6.3 Economic strata

The difference between the prevailing market rates and the base rate referred to as economic strata was determined through the use of neural networks. The software selected for neural network was NeuroShell2. NeuroShell2 has different network architectures which are either supervised or unsupervised. The Kohonen architecture was used because it is unsupervised and has the ability to learn without being shown correct outputs in sample patterns. The Kohonen self-organizing map network was able to separate data patterns of the established 8 factors which have been incorporated in the model.

3.6.4 UCEM

The model software was developed using ASP.NET 4 with the C# programming language. The model uses Microsoft SQL Server 2012 as the database engine. The model is standalone and does not use any content management system (CMS). The model is web based. The model integrated qualitative neural network factors and quantitative base rates to produce a unit cost rate. The model output is the BoQ descriptions with their associated unit rates. If quantities are added to the model, the total price is subjected to value added tax (VAT) to reveal the project cost estimate.

3.6.5 Validation

The concept of validation is an accepted form of critique (Muya, 1999). Validation is the task of demonstrating that the model is a reasonable representation of the actual system; that it reproduces system behaviour with enough fidelity to satisfy analysis objectives (Hillston, 2003). Hillston (2003) further states that there were three approaches to model validation and any combination of them could be applied as appropriate to the different aspects of a particular model. These approaches are: real system measurements; expert intuition; and theoretical results analysis.

i. Real system measurements

Comparison with a real system is the most reliable and preferred way to validate a simulation model. In practice, however, this is often infeasible either because the real system does not exist or because the measurements would be too expensive to carry out. Assumptions, input and output values, workloads, configurations and system behaviour should all be compared with those observed in the real world. In the case of simulation models, when full measurement data is available it may be possible to use trace-driven simulation to observe the model under exactly the same conditions as the real system.

ii. Expert intuition

Expert intuition involves examination of the model by someone other than the modeller, an "expert" with respect to the system, rather than with respect to the model. This could be the system designer, service engineers or marketing staff, depending on the stage of the system within its life-cycle. Careful inspection of the model output, and model behaviour, tracing and animation, in the case of simulation models, and the full steady state representation of the state space in the case of Markovian models. In either case, a model may be fully instrumented, meaning that every possible performance measure is extracted from the model for validation purposes regardless of the objectives of the performance study.

iii. Theoretical results analysis

In the case of detailed Markovian models or simulation models, it is sometimes possible to use a more abstract representation of the system to provide a crude validation of the model. In particular, if the results of a function analysis based on the operational laws coincide with model output it may be taken as evidence that the model behaves correctly. Another possible use for operational laws is to check consistency within a set of results extracted from a simulation model. If the model is behaving correctly it would be expected that the measures extracted during its evolution obey the operational laws provided for the usual assumptions hold. Failure of the operational laws would suggest that further investigation into the detailed behaviour of the model was necessary.

3.7 Summary

Chapter Three described common research methodologies and the available methods used to collect data. Though this research was skewed towards a positivist approach, it adopted a mixed or combined method. Using the mixed method of research enabled collection of multiple data using different strategies, approaches, and methods in such a way that the resulting mixture or combination resulted in complementary strengths and non-overlapping weaknesses. The study was generally identified as correlational resulting in correlation coefficients and regression equations. Primary data was collected through expert opinion and questionnaire surveys and secondary data through survey of related studies. The internet was established as the main electronic source for secondary data while books, journals and newspapers were the paper based sources. Validation was an important aspect of the methodology to demonstrate that the model was behaving appropriately. Real systems measurement, expert intuition and theoretical results analysis were performed to validate the developed model. Chapter Four discusses how the cost factors were determined and analysed ready for model formulation.

Chapter Four: Establishment of Cost Factors

4.1 Introduction

Chapter Three presented various research methods available in the field of cost estimation and described the methodology adopted for the study. This chapter examines the overall approach to the establishment of cost factors in the Zambian road sector. Factors affecting construction unit costs vary depending on a country's political, economic, social and technological inclinations. Analysis of cost factors requires an appreciation of a country's practices. Identified cost factors provide an indication of a country's construction economic strata.

In cost estimation, selecting cost drivers or factors is an important step (Blocher et al., 2008). A cost estimation model's accuracy is based on selecting the relevant and appropriate drivers (ibid). Al-Tabtabai et al., (1999) stated that effective construction project estimating is dependent on experience. He further stated that determining the change in cost is often a fuzzy, qualitative, and ill-structured process, which is frequently performed by estimators in a heuristic and intuitive fashion. Project cost experts with experience in a specific construction area usually judge the percentage increase they anticipate in upcoming projects with respect to a standard reference project. These experts analyse the magnitude and effect of various factors on the estimate in order to estimate the perceived change from the reference cost, and thus the amount necessary for profitable construction (Al-Tabtabai et al., 1999). From reviewed literature it was observed that the selection of cost factors was dependant on the experience and expertise of industry professionals. A number of techniques such as Delphi, nominal group technique or expert interviews were available to acquire tacit knowledge based on the expertise of construction specialists. In this study, determination of cost factors used a two-step process: expert opinion followed by a questionnaire survey.

4.2 Expert opinion

Expert opinion is an estimating technique where specialists are consulted and consensus is formed regarding task, activity, project, or programme (DOE, 2011). Expert opinion is an informal technique but was adapted using the Delphi technique to establish a more formal data collection method. The Delphi technique is appropriate when (Linstone and Turoff, 2002):

a) the problem does not lend itself to precise analytical techniques but can benefit from subjective judgments on a collective basis;

b) the individuals needed to contribute to the examination of a broad or complex problem have no history of adequate communication and may represent diverse backgrounds with respect to experience or expertise;

c) more individuals are needed than can effectively interact in a face-to-face exchange;

d) time and cost make frequent group meetings infeasible;

e) the efficiency of face-to-face meetings can be increased by a supplemental group communication process;

f) disagreements among individuals are so severe or politically unpalatable that the communication process must be refereed and/or anonymity assured; and

g) the heterogeneity of the participants must be preserved to assure validity of the results, such as avoidance of domination by quantity or by strength of personality ("bandwagon effect").

Linstone and Turoff (2002) further stated that the Delphi technique involves four distinct phases:

a) the first phase is characterized by exploration of the subject under discussion, wherein each individual contributes additional information they feel is pertinent to the issue;

b) the second phase involving the process of reaching an understanding of how the group views the issue such as where the members agree or disagree and what they mean by relative terms such as importance, desirability, or feasibility;

c) if there is significant disagreement, then that disagreement is explored in the third phase to bring out the underlying reasons for the differences and possibly to evaluate them; and

d) the last phase, the final evaluation, occurs when all previously gathered information has been initially analysed and the evaluation has been fed back for consideration.

In the partial Delphi adapted in this study, only phases one and two were conducted. It was difficult to bring ten experts together at the same time, therefore the participants never met. Though Delphi is normally associated with forecasting (Linstone and Turoff, 2002), the expert opinions were required initially to select variables identified from literature that apply to the Zambian road sector. Hasan (2013) employed the Delphi technique to evaluate tacit knowledge based on the experience of individual practitioners to determine the influential factors on road project costs in Gaza strip. Yousuf (2007) stated that in the Delphi technique the panel's viewpoints are summarized statistically rather than in terms of a majority vote. The expert opinion results were statistically analysed using the Pareto analysis.

4.2.1 Expert panel composition

Ten professionals' incorporating five civil engineers and five quantity surveyors with experience in costing of road works in Zambia were targeted. The selection criteria were as follows:

a) minimum academic qualification of first degree;
b) background in civil engineering or quantity surveying;
c) more than 10 years' experience;
d) able to build up road construction rates from first principles; and
e) worked on a project valued at NCC Grade 3 minimum limit of contract value under category R (roads).

Only seven out of the targeted ten professionals participated. Of the seven experts, five had over twenty years of experience in road infrastructure estimating while of the remaining two, one had twelve and the other fourteen years of experience. All the experts held management positions within their organisations. One (1) was from the clientele, two (2) from consultancy, two (2) were contractors and two (2) from academia that teach estimating principles. This process was conducted between February and March 2014.

4.2.2 Experts' perception of identified factors

From literature review, 45 cost factors that influence unit rates in roadworks were identified and sent to the experts for comments. Feedback from experts resulted into the variables being divided into four categories namely country; road sector; contractor: and project specific as presented in Table 4.1.

Table 4.1: Categorised cost factors

Country specific: (for comparison with other countries) Country classification, Human Development Index (HDI), The Global competitive index (GCI), Ease of doing business, Corruption Perception Index, Gross Domestic Product, Total road network (km), Road density (km of road per 100 sq. km of land area), Total % of paved roads
Road Sector specific: (includes regulations and policies imposed by road sector regulators) Land acquisition, Project need, delayed payment, Contract financing or financial assessment, political risk, advance payment provisions, 20% subcontracting, HIV training, project consultant, Project planning and management, quality of bidding documents, Price adjustment clause, Contractor selection method, Road type, Exchange rate, Material shortages, Material Source, Competition, environmental (EIA) project site restoration,
Contractor Specific: Contractor size, Contractor type, Labour, Equipment availability, contractor cashflow, overhead & profit
Project Specific: Road length, Duration, Year, Project scope, Culvert crossings, Location, Hauling distance, Detour, Utilities, Soil condition, Climate

The experts were requested to indicate their opinions and perception of the cost factors identified.

i. Location

All experts agreed that location was a major factor in bidding for contracts. One expert revealed that mobilisation costs were about 10 percent higher for areas such as Shangombo which is about 900 kilometres from Lusaka and considered as one of the remotest areas of Zambia. However, further investigations were required to ascertain the ascribed percentage difference in costs.

ii. Haulage distance

Again all experts agreed that hauling distance in transporting material and equipment had a high impact on cost. In fact, five of the seven experts emphasised that as such fuel should be included as a separate factor.

iii. Delayed payments

Experts stated that delayed payments in the Zambian road sector were highly prevalent. It was agreed that stakeholders factored potential delays in payment into their pricing of contracts. Apart from delays resulting in slowing down or suspension of on-going works, three experts felt that this was a source of fraudulent activities in the sector.

iv. Project planning and management

Inclusion of project planning and management as a high impact cost factor gave an insight into the operations of the road sector in Zambia. Experts felt that issues that led to the increase of cost due to this factor included: the practice of appointing supervision consultants after appointing the main contractor; procuring works without sufficient budget allocations; incomplete or uncoordinated bid documents calling for more addenda during tendering; proceeding with projects before they are well defined; improper use and calculation of contingencies; lack of engineer's estimates; and absence of appropriate economic models in the estimating process.

v. Foreign exchange rate

Only two out of the seven experts stated that the inflation rate should be used as opposed to the exchange rate. Even though all payments on road contracts were made in Zambian Kwacha with a price adjustment clause in contracts longer than 18 months, five experts stated that the exchange rate was appropriate because road contracts had high import content of input costs such as bitumen, equipment purchase and associated maintenance for aspects like spare parts, steel reinforcement and fuel. One expert went on to state that the percentage of fuel increase could be used as a unit cost index.

vi. Other factors

Experts revealed that advance payment, the type of project consultant and competition had minimal influence on prevailing market rates contrary to a previous study conducted by RDA (2009) which indicated that:

a) when advance payments were removed from Government construction contracts in 2008, the impact on contractors' prices was significant as the cost of borrowing in Zambia was high. However, experts felt the position was different today;
b) knowing supervising consultants was important even though the impact was not stated. The experts felt this had minimal effect; and
c) lack of competition was a factor in increasing unit rates on larger contracts, particularly since 2008 when competition reduced and a large number of contracts were tendered. Contractors tended to increase their prices.

During discussions, additional factors were highlighted such as political interference. Experts felt that the fact that RDA was under the Office of the President increased the risk profile of the construction industry. Even though energy costs were included as part of plant and equipment productivity, it was emphasised that energy costs such as fuel should be a stand-alone item. It was recommended that soil and climate factors be combined and renamed as topography. Other factors considered were contractor work conditions, inflation, funding source, design criteria such as number of lanes, pavement layers and base material. Four out of the seven experts argued that project scope or design criteria could not be a factor as that was part of actual costs of construction. Under country specific factors one expert mentioned that a country's stability contributed to unit costs.

The expert opinion analysis showed that where as advance payment, the type of project consultant and competition were influential when an investigation into factors was undertaken by RDA in 2008 in the Zambian road sector, they were no longer significant five years later. This result emphasised the finding from literature review which indicated that periodic review of cost factors was essential because of countries' constant political, economic social and technological transformations.

4.2.3 Pareto analysis

The second phase of the Delphi exercise was to reach an understanding of how the experts viewed the identified cost factors in terms of impact on unit costs. The experts were requested to indicate the impact of cost factors on unit rates based on the Likert scale of 1 to 5 where 1 meant no impact and 5 represented extremely high impact. Factor ranking was done using SPSS through sum and mean statistics. Once this was done, the Pareto Analysis was used to determine the 20 percent influential factors. Pareto Analysis is a statistical technique in decision making used for the selection of a limited number of tasks that produce significant overall effect. Cronbach's alpha was considered but it was decided that Pareto's law was more appropriate for this stage of analysis. Cronbach's alpha is a measure of internal consistency. It is a coefficient of reliability or consistency. At this stage, the analysis was not considering consistency of the factors but the important factors. Using the Pareto Principle also known as the 80/20 rule, the influencing factors were determined in ascending order using a Pareto diagram. A Pareto diagram is a histogram, arranged by frequency of occurrence, which shows how many results were generated by each identified cause (AACE, 2013). From the Pareto diagram shown as Figure 4.1, the number of factors was reduced to 31.

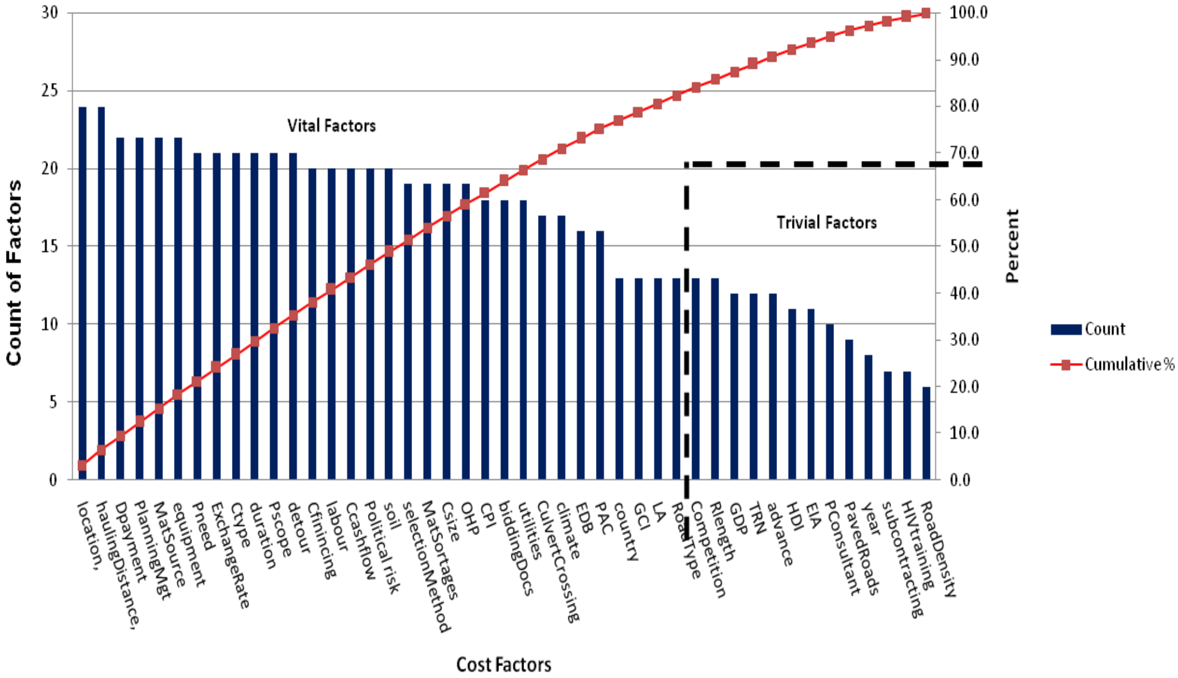


Figure 4.1: Pareto analysis

The factors shown in Table 4.2 were referred to as variables as they were still going to be subjected to a questionnaire survey.

Table 4.2: List of most influential cost variables after Pareto Analysis

1. Location	Most Influential
2. Hauling distance	
3. Delayed payment	
4. Project planning and management	
5. Material Source	
6. Equipment availability	
7. Project need	
8. Exchange Rate	
9. Contractor type	
10. Duration	
11. Project scope	
12. Detour	
13. Contract financing	
14. Labour	
15. Contractor cash-flow	
16. Political risk	
17. Soil	
18. Contractor selection method	
19. Material Shortages	
20. Contractor size	
21. Overhead & Profit	
22. Corruption Perception Index	
23. Quality of bidding documents	
24. Utilities	
25. Culvert Crossing	
26. Climate	
27. Ease of doing business	
28. Price adjustment clause	
29. Country classification	
30. The Global competitive index	
31. Land Acquisition	Least influential

The 31 cost variables were further reduced to 22 after taking into account recommendations from experts. Climate and soil were combined under topography. It was stated that the majority of road contracts in Zambia were of fixed sum type, therefore the price adjustment clause had minimal effect and was thus removed. Other variables, namely: ease of doing business; country classification; and global competitive index were removed on account of being applicable when country comparisons were being made. Experts advised that land acquisition was a factor of a client and not contractor therefore it was omitted. They stated that the quality of bidding documents was included under project planning, and therefore it was dropped. It was stated that displacement of utilities for roadworks was not a major factor as there was no road project mentioned which involved displacement of existing infrastructure. Three (3) factors, namely fuel, project supervision and management, and client type were added to the list following expert recommendation. The 25 variables subjected to the questionnaire survey are shown in Table 4.3. From Table 4.3, Variable 1 was the most significant and Variable 22 the least influential with 23 to 25 as the added variables.

Table 4.3: List of cost variables subjected to questionnaire survey

1. Location	9. Contractor type	17. Topography
2. Hauling distance	10. Duration	18. Contractor selection method
3. Delayed payment	11. Project scope	19. Material Shortages
4. Project planning	12. Detour construction	20. Contractor size
5. Material Source	13. Contract financing	21. Overhead & Profit
6. Equipment availability	14. Labour	22. Corruption Perception Index
7. Project need	15. Contractor cash-flow	23. Fuel
8. Exchange Rate	16. Political risk	24. Project supervision & management
		25. Client type

Generally, all factors that were included under the contractor specific category scored high on the ranking implying that any changes on unit costs would have to target the contractor.

4.3 Questionnaire survey

To obtain a conclusive result on factors influencing road construction unit rates, the 25 factors were subjected to a questionnaire survey. Respondents were asked questions regarding the impact of cost factors on unit rates based on the Likert scale of 1 to 5 where 1 represented no impact and 5 represented extremely high impact. A sample of the questionnaire is attached as Appendix A. This process was conducted between March and May 2014.

4.3.1 Population and sample size

The sample respondent population consisted of civil engineers with experience in cost estimation of roadworks. Equation 4.1 was used to determine the sample size of an infinite population (Cooper and Schindler, 2011; Creative Research Systems, 2014).

$$ss = \frac{z^2 \times p \times (1-p)}{c^2}$$

Equation 4.1

where:

z = Z value, e.g. 1.96 for 95% confidence level;
p = percentage picking a choice, expressed as decimal (0.5 used for sample size needed);
c = confidence interval, expressed as decimal (0.5 = ±5); and
ss = sample size.

$$ss = \frac{1.96^2 \times 0.5 \times (1-0.5)}{0.5^2} = 384$$

Equation 4.2

The correction for the finite population was:

$$NewSS = \frac{ss}{1 + \frac{ss-1}{pop}}$$

Equation 4.3

where:

pop = population

$$NewSS = \frac{384}{1 + \frac{384-1}{108}} = 84$$

Equation 4.4

The sample population targeted all the 72 large scale contractors in National Council for Construction (NCC) Grades 1 to 3 in the R (road) category. At the time of the survey there were 26 registered civil engineering consulting firms with the Association of Consulting Engineers of Zambia (ACEZ) and 10 clientele organisations that dealt with estimation of roadworks. The total population size was 108 and the calculated sample size from Equation 4.4 was 84. The questionnaires were distributed proportionately to the three groups as follows:

a) Contractors: 84 x 72/108 = 56 (actual distribution = 30);
b) Consultants: 84 x 26/108 = 20 (actual distribution = 20); and
c) Clients: 84 x 10/108 = 8 (actual distribution = 8).

A total of 58 questionnaires were distributed. Twenty six (26) contractors could not be located using the contact details from the contractor registration institution, NCC. The response rate was 69 percent. Rubin and Babbie (2010) stated that a response rate of 50 percent was considered adequate for analysis and reporting. They further said that a response rate of 60 percent was good and 70 percent was very good. However, Rubin and Babbie (2010) emphasised that a demonstrated lack of response biasness was far more important than a high response rate.

Analysis was conducted using Statistical Package for Social Sciences (SPSS) version 20. In particular, factor analysis was performed to reduce the factors further from the list of 25 derived using the Pareto theory and expert opinion. There is concern among researchers that factor analysis with small sample sizes does not yield good quality results. De Winter et al. (2009) stated that a sample size of 50 was an acceptable absolute minimum for factor analysis. But in their study, De Winter et al. (2009) showed that factor analysis could still yield good quality results for sample sizes less than 50. They reported that when the data was well conditioned, factor analysis yielded reliable solutions for sample sizes smaller than 10. Simulations showed that when the structure was simple it was possible to correctly estimate the number of factors (ibid).

4.3.2 Factor analysis

SPSS factor analysis was performed to reduce the factors further by analysing the correlation between the variables and whether the grouped factors were statistically significant. The principal components extraction was used. Each eigenvalue represents the amount of variance that has been captured by one component. Table 4.4 shows the eigenvalues and proportions of variance for the components.

Table 4.4: Total variance explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	6.518	26.073	26.073	6.518	26.073	26.073	3.738	14.953	14.953
2	3.652	14.608	40.681	3.652	14.608	40.681	3.328	13.311	28.265
3	2.665	10.659	51.340	2.665	10.659	51.340	3.105	12.418	40.683
4	2.139	8.556	59.896	2.139	8.556	59.896	2.711	10.846	51.529
5	1.876	7.506	67.402	1.876	7.506	67.402	2.168	8.674	60.203
6	1.574	6.295	73.697	1.574	6.295	73.697	2.158	8.631	68.833
7	1.239	4.957	78.654	1.239	4.957	78.654	1.928	7.711	76.544
8	1.171	4.684	83.338	1.171	4.684	83.338	1.698	6.794	83.338
9	.976	3.905	87.242						
10	.866	3.463	90.706						
11	.568	2.271	92.977						
12	.485	1.939	94.916						
13	.345	1.380	96.296						
14	.293	1.172	97.468						
15	.276	1.103	98.571						
16	.180	.720	99.291						
17	.130	.519	99.810						
18	.047	.190	100.000						
19	3.664E-16	1.466E-15	100.000						
20	1.570E-16	6.279E-16	100.000						
21	1.010E-16	4.041E-16	100.000						
22	5.574E-17	2.230E-16	100.000						
23	-7.602E-17	-3.041E-16	100.000						
24	-2.913E-16	-1.165E-15	100.000						
25	-4.500E-16	-1.800E-15	100.000						

Extraction Method: Principal Component Analysis.

From Table 4.4, the total of the rotation sums of squared loadings was 1 or more in eight components. To classify the components, an orthogonal factor rotation analysis was conducted, and the rotated component matrix was analysed, as given in Table 4.5. The rotation method used was Varimax with Kaiser Normalization suppressing variable values less than 0.400.

Table 4.5: Rotated component matrix

Variable	Component							
	1	2	3	4	5	6	7	8
contractor_size	.837							
contractor_type	.819							
financial_status_or_cashflow_of_contractor	.815							
client_type	.755							
hauling_distance		.815						
location_of_the_project		.814						
fuel		.756						
exchange_rate		.634	.503					
procurement	.536	.631						
payments			.804					
construction_workers			.768					
topography			.766					
detour_construction			.662					
project_scope				.817				
contract_financing				.751				
project_planning				.701				
project_need	.499			.527				
project_management	.445				.722			
overhead_and_profit					-.710			
plant_and_equipment					.680			
material_sources						.881		
material_shortages						.836		
corruption_perception_index							.846	
project_duration							-.709	
political_interference								.844

To reclassify the eight components, results from Tables 4.4 and Table 4.5 were interpreted collectively. The eight components were named according to the loading of the variables in the rotated solution ensuring that the factor name was brief and that it communicated the nature of the underlying factors.

The contractor variables loaded well on the first component, reflecting how clients perceived contractors. The principal first factor thus labelled *'contractor capacity'* accounted for 26.073 percent of the total variance and contained seven variables. The second component appeared to be reflecting location of the project versus economy. It was labelled *'project location'* and had five variables representing 14.608 percent of the total variance. The third component labelled *'period of honouring payments'* accounted for 10.659 percent of the total variance, with five variables and showed the effect of contractual period of payments on the exchange rate, construction workers and the type of work to be carried out. The fourth component focused on projects pre-planning activities. It was labelled *'project feasibility'* with four variables and represented 8.556 percent of the total variance. The fifth component was more interesting, with a negative loading on overheads and profit. It had three variables reflecting overheads and profit, plant and equipment and the projects management's capacity. It was labelled *'cost escalation'* and represented 7.506 percent of the total variance. Component six labelled *'material availability'* was straight forward and reflected material factors with two variables representing 6.295 percent of the total variance. The seventh component was also interesting, with a negative loading reflected concern for corruption versus duration of the project. It was labelled *'country corruption profile'* with two variables and accounted for 4.957 percent of the total variance. The last eighth component labelled *'political environment'* reflected concern for political intrusion. It had one variable and accounted for 4.684 percent of the total variance. The renamed eight factors are shown in Table 4.6.

Table 4.6: Established cost factors

Component	Cost factor	Eigenvalues (% of Variance)	Number and range of Variables (more than 0.400)
1	Contractor capacity	26.073	7 from 0.445 to 0.837
2	Project Location	14.608	5 from 0.631 to 0.815
3	Period of honouring payments	10.659	5 from 0.503 to 0.804
4	Project feasibility (pre-construction)	8.556	4 from 0.527 to 0.817
5	Cost escalation	7.506	3 with values of 0.722, 0.680 and -0.710
6	Materials availability	6.295	2 with values of 0.881 and 0.836
7	Country corruption profile	4.957	2 with values of 0.846 and -0.709
8	Political environment	4.684	1 with a value of 0.844

After establishing the influential factors, prediction of the breakdown of the factors on unit costs was achieved using artificial neural network.

4.4 Summary

Chapter Four established eight (8) factors namely: contractor capacity; project location; period of honouring payments; project feasibility at pre-construction phase; escalation; materials availability; country corruption profile; and political environment affecting unit costs in the Zambian road sector. Analysis of cost factors requires an appreciation of a country's practices. The identified cost factors provided an indication of a country's construction economic strata. The Zambian road economic strata revealed that contractors have to deal with financial delays in the sector, long haulage distances and questionable project planning and management from public client institutions. Chapter Five presents results from neural network training of the eight factors.

Chapter Five: Neural Network Training and Testing

5.1 Introduction

Chapter Four presented the formulation of factors affecting construction unit cost. Eight major factors were established, namely: contractor capacity; project location; period of honouring payments; project feasibility; escalation; material availability; country corruption profile; and political environment. The identified cost factors provided an indication of the Zambian road economic strata. This chapter details how the eight factors were subjected to neural network training and testing.

Literature review revealed that there was no limit to the number of factors or variables to be used in neural network training. Al-Tabtabai et al. (1999) used 9 factors in developing a preliminary cost estimate of highway construction using neural networks. Reviewed literature revealed that an ideal number of input factors used in similar studies in neural network averages 9.9. Therefore, the eight factors established from the questionnaire survey were determined to be acceptable.

5.2 Factor input for neural network

Contract documents for 254 projects were made available by the Road Development Agency (RDA). These projects were executed during a ten year period from 2005 to 2014. Data from these projects was used in the training of the neural network. Ward Systems (2014) the developer of neural network software, NeuroShell2, indicate that to train the network a good rule of thumb is the number of training patterns should equal 10 times the number of inputs. Therefore, having the number of projects for training above eighty (80) was considered more than adequate.

5.2.1 Establishment of factor input nodes

To train a neural network, data has to be relayed through the input layer to the output layer. The input layer nodes are passive doing nothing but relaying values from their single inputs to their multiple outputs (Smith, 1997). An input is a variable that a network uses to make a classification or prediction. It is sometimes referred to as an independent variable. Input can be numeric or text. Numeric data type was selected for easy input. Associated input nodes were derived for the determined eight factors.

i. Contractor capacity

Contractor capacity was determined by considering the National Council for Construction (NCC) contractor classification system. The NCC categorises contractors in terms of technical capacity and area of specialisation. The NCC Grades 1 to 6 consider contractors' capacity where Grades 1 to 2 are large scale contractors, Grades 3 to 4represent medium scale contractors and Grades 5 to 6are entry level or small scale contractors. In terms of area of specialisation, NCC has 6 categories namely: General Building and Housing (B); General Civil Engineering Works (C); General Roads and Earthworks (R); General Mining Services (M); Electrical and Telecommunications (E); and Specialised work (S). The focus of the study was contractors in the R category. Therefore, the derived input nodes for contractor capacity were: 1 = Grade 1; 2 = Grade 2; 3 = Grade 3; 4 = Grade 4; 5 = Grade 5; 6 = Grade 6; and 7 = ungraded.

ii. Project location

Project location was estimated as approximate distance of the project from the capital city, Lusaka. The GRZ (2014) on the Zambia distance table calculates the most practical and not necessarily the shortest routes. The Zambia distance table showed that the furthest distance between any two towns was 1772 km from Lundazi to Mbala. But the furthest from Lusaka, which is centrally located, was 1016 km to Mbala. Project location was calculated from Lusaka because it was a general practice that contractors mobilised from Lusaka. This assumption was confirmed after analysing the project details obtained which indicated that about 92 percent of the contractors in R category mobilised from Lusaka. From the form of agreement signed, all these contractors indicated that their registered company addresses were in Lusaka. Therefore, the derived input nodes for project location were: 1 = very near (<100km); 2 = near (101-300km); 3 = average (301-500km); 4 = far (501-700km); 5 = very far (701-900km); and 6 = extremely far >901km.

iii. Period of honouring payments

The sampled contracts indicated the period of honouring payments in the general conditions of contract varied between 28 and 84 days after the Engineer receives the statement and supporting documents. The contractor therefore has to factor costs for that period. Therefore, the derived input nodes for period of honouring payments were: 1=

up to 28 days; 2= up to 35 days; 3 = up to 42 days; 4= up to 49 days; 5= up to 56 days; 6= up to 63 days;7= up to 70 days; 8= up to 77 days; and 9= up to 84 days.

iv. Project feasibility (pre-construction)

In factor analysis, the variables that were grouped to form the factor named project feasibility were: Project_Scope; Contract_Financing; Project_Planning; and Project_Need. The major concern under project feasibility was the tendency of appointing consultants after awarding works to the main contractor. The derived input nodes for project feasibility were: 1= very good; 2= good; 3= satisfactory; 4= poor; and 5= unacceptable.

v. Cost escalation

Escalation may include general inflation related to the money supply, but it is primarily specific to labour, material and machinery price trends. It covers the potential increase in cost of the project's inputs. Figure 5.1 shows the trend for general inflation, consumer price index and cement prices from 2009 to 2014.

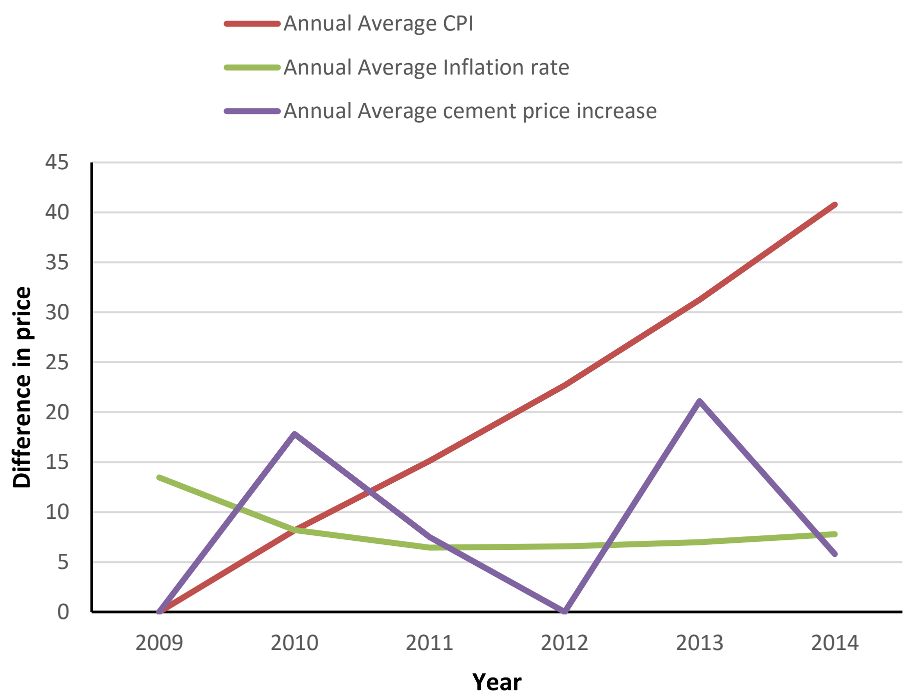


Figure 5.1: Consumer price index, inflation and cement prices 2009 – 2014
(After CSO, 2014)

For the period 2009 to 2014 the average annual general inflation was 8.24 percent. The average annual consumer price index was 19.67 in the same period. The cement prices escalation was 8.7 percent. Figure 5.2 shows Zambia ex-factory price trend for the three players in the cement production sector.

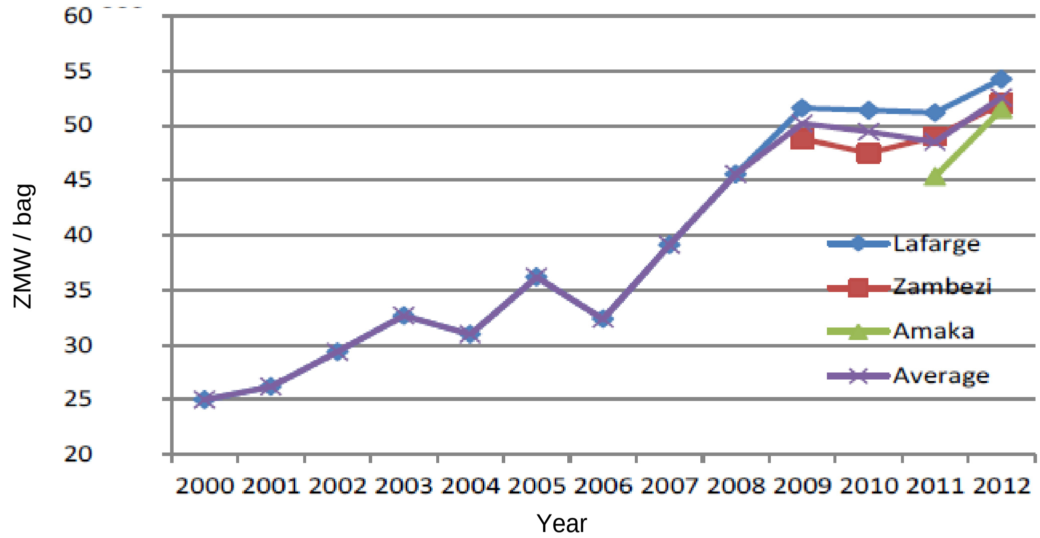


Figure 5.2: Zambia ex-factory price trend for the three players in the sector
(Source: Mbongwe et al., 2014)

Mbongwe et al. (2014) noted that Zambia's prices remained above those of the other countries as shown in Figure 5.3.

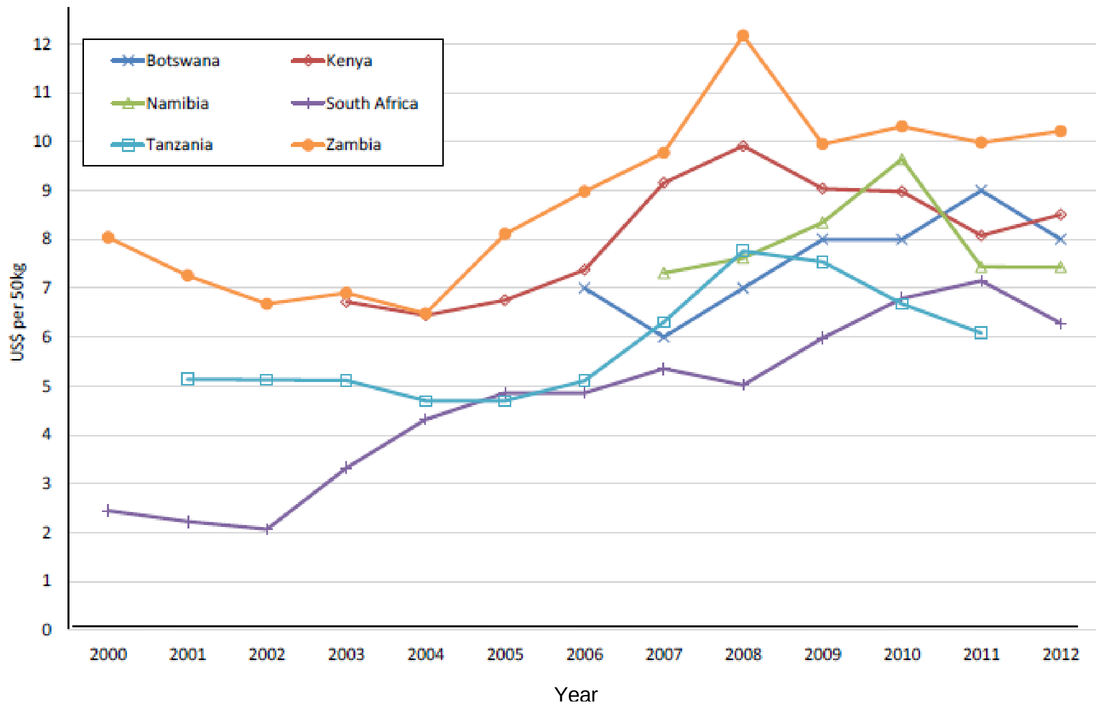


Figure 5.3: Estimated ex-factory cement prices of 50kg bag in US$
(Source: Mbongwe et al., 2014)

The international comparisons show that Zambian ex-factory prices were substantially higher than in other countries over the period, and at times close to double those in South Africa, the lowest priced country. The trend is the same when considering fuel. Table 5.1 shows the gasoline retail prices in SADC in US cents per litre for selected years (SADC, 2012b).

Table 5.1: Super gasoline retail prices in SADC in US cents per litre, 1991 - 2010, selected years

Country	1991	1993	1995	1998	2000	2002	2004	2006	2008	2010
Angola				38.0	30.0	19.0	39.0	50.0	53.0	65.0
Botswana	68.0	41.0	38.0	31.0	42.0	41.0	66.0	78.0	88.0	93.0
Democratic Republic of Congo	81.0	74.0	73.0	50.0	100.0	70.0	92.0	94.0	123.0	
Lesotho				39.0	50.0		73.0	89.0	79.0	97.0
Madagascar	43.0	54.0	47.0	47.0	76.0	108.0	105.0	115.0	155.0	152.0
Malawi	64.0	71.0	65.0	51.0	69.0	66.0	95.0	117.0	178.0	171.0
Mauritius				55.7	55.1	67.2	83.2	115.8	153.1	142.7
Mozambique	74.0	48.0	53.0	55.0	56.0	46.0	88.0	115.0	171.0	111.0
Namibia	46.0	42.0		38.0	47.0	45.0	68.0	87.0	78.0	106.0
Seychelles								135.0	91.0	
South Africa		52.0	51.0	43.0	50.0	43.0	81.0	85.0	65.0	119.0
Swaziland	46.0	43.0		37.0	47.0		76.0	80.0	86.0	107.0
Tanzania	42.0	43.0	56.0	63.0	75.0	67.0	93.0	104.0	111.0	122.0
Zambia	40.0	72.0	60.0	53.0		72.0	110.0	131.0	170.0	166.0
Zimbabwe	68.0	47.0	38.0	26.0	85.0	5.0	61.0		130.0	129.0

From Table 5.1 the price of gasoline for Zambia moved from the lowest in 1991 at US$ 0.40 to the highest at US$ 1.66 per litre in 2010, second only to Malawi. The assumption therefore is that the unit rates of the Zambian road sector were expected to be higher than those in the region.

The Zambian road sector uses the consumer price index for price adjustments for contracts longer than 18 months. Clearly this practice is not appropriate and construction specific indices need to be developed to determine the level of escalation.

Nonetheless, the derived input nodes for cost escalation were: 1 = 0 percent; 2 = 5 percent; 3 = 10 percent; 4 = 15 percent; 5 = 20 percent; 6 = 25 percent; 7 = 30 percent; and 8 = above 35 percent.

vi. Materials availability

The Zambian road sector has both local and imported materials. Materials availability has been stable. The last severe construction shortage was in the mid-eighties at the time of auctioning for foreign exchange. The kwacha, the Zambian currency, quickly depreciated from K2.2/dollar to K6/dollar affecting imports (Bates and Collier, 1994). Materials available locally means that both imported and local materials were available. Available internationally means that there were restrictions on importing material into the country. Shortage means the local materials were scarce locally but available internationally and severe shortage means materials were not available both locally and internationally. Therefore, the derived input nodes for material availability were1 = available locally; 2 = available imported; 3 = shortages; and 4= severe shortages.

vii. Country corruption profile

Corruption perception index (CPI[1]) is a ranking of countries according to the extent to which corruption is believed to exist. The corruption perception index was created in 1995 by Transparency International. Zambia was only profiled from 1998 onwards. The derived input nodes for country corruption profile based on compilation by Transparency International were: 1=very clean (100 to 80), 2= clean (79 to 60), 3= moderate (59 to 40), 4= corrupt (39 to 20), 5= highly corrupt (19 to 0).

viii. Political environment

The country political environment relates to political interference as perceived by stakeholders. Political risk is seen as a risk as a result of political changes or instability in a country from a change in government or legislative bodies. The transfer of RDA to the Office of the President in 2011 was perceived as increased political risk. The relationship between the government and foreign contractors was also considered as a political risk. Based on the above assumptions, projects commenced before 2011 were rated as moderate and those with a start date after 2011 were categorised as having high political interference. Of the eight factors, this was the most subjective and further studies would be required to quantify the risk for the Zambian scenario.

Multilateral Investment Guarantee Agency (2014), amongst its findings, indicated that political risk ranked in fourth place out of twenty in terms of its difficulty to forecast. To introduce objectivity to this factor, the Worldwide Governance Indicators (WGI) were considered. Governance consists of the traditions and institutions by which authority in a country is exercised (World Bank, 2014). It includes the process by which governments are selected, monitored and replaced; the capacity of the government to effectively formulate and implement sound policies; and the respect of citizens and the state for the institutions that govern economic and social interactions among them (World Bank, 2014). In other words, governance refers to a political environment of a country. The WGI project aggregated individual governance indicators for 215 economies over the period 1996 to 2013 for six dimensions of governance namely:

a) Voice and Accountability;
b) Political Stability and Absence of Violence;
c) Government Effectiveness;
d) Regulatory Quality;
e) Rule of Law; and
f) Control of Corruption.

The percentile rank from 0 to 100, with higher values corresponding to better outcomes, has been used. Figure 5.4 shows Zambia's percentile rank of the six WGI.

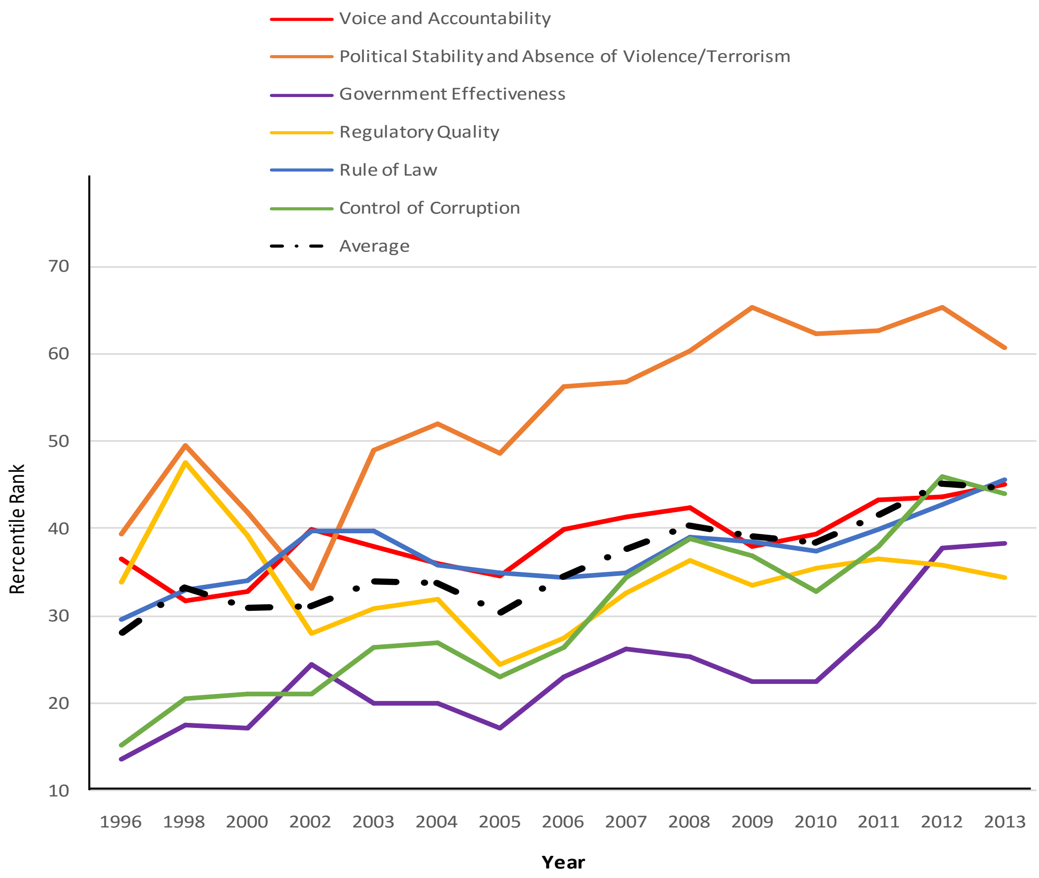


Figure 5.4: Percentile rank of the six WGI for Zambia (after World Bank, 2014)

Figure 5.4 shows that though Zambia's stability is good, government effectiveness is poor. The average scores for all six WGI place Zambia below 50 percent in the 25 to 50 percentile range. In summary, the political environment considered the governance structures, regulation and level of political influence in the running of the Zambian road sector. The derived input nodes based on political interference in road projects were: 1=none; 2= low; 3= moderate; 4= high; and 5= very high.

The input nodes for the eight factors used in the study are shown in Table 5.2.

Table 5.2: Established factors and associated input nodes

S/No.	Cost factor	Factor Input for neural network
1	Contractor capacity	Capacity of contractor 1 = Grade 1; 2 = Grade 2; 3 = Grade 3; 4 = Grade 4; 5 = Grade 5; 6 = Grade 6; 7 = ungraded
2	Project Location	Distance in km from Lusaka or urban location 1 = very near (<100km); 2 = near (101-300km); 3 = average (301-500km); 4 = far (501-700km); 5 = very far (701-900km); 6 = extremely far >901km
3	Period of honouring payments	1= up to 28 days; 2= up to 35 days; 3 = up to 42 days; 4= up to 49 days; 5= up to 56 days; 6= up to 63 days; 7= up to 70 days; 8= up to 77 days; and 9= up to 84 days
4	Project feasibility (pre-construction)	1= very good; 2=good; 3= satisfactory; 4= poor; 5=unacceptable
5	Escalation	1 = 0%; 2 = 5%; 3 = 10%; 4 = 15%; 5 = 20%; 6 = 25%; 7 = 30%; 8 = above 35%
6	Materials availability	1 = available locally; 2 = available imported; 3 = shortages; 4= severe shortages
7	Country corruption profile	Corruption Perception Index (CPI[1]) compiled by Transparency International 1=very clean (100-80); 2= clean (79-60); 3= moderate (59-40); 4= corrupt (39-20); 5= highly corrupt (19-0)
8	Political environment	Political interference 1=none; 2= low; 3= moderate; 4= high; 5= very high

5.2.2 Calculation of project factor input

Contractor capacity was obtained from the NCC registration certificate in the tender documents. The input for this factor from the projects analysed is shown in Figure 5.5.

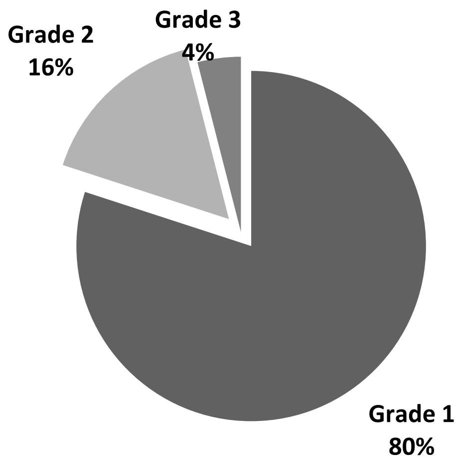


Figure 5.5: Breakdown of NCC contractor grade

For project location the input data is shown in Table 5.3.

Table 5.3: Input data for project location

S/No.	Input Description	Project totals in percent
1	1= very near	4%
2	2= near	16%
3	3= average	24%
4	4= far	28%
5	5= very far	24%
6	6= extremely far	0%

Periods of honouring payments were obtained from special conditions of contract. If nothing was specified, then 1 = up to 28 days was used as this was the standard practice. The input data for period of honouring payments is shown in
Table 5.4.

Table 5.4: Input data for period of honouring payments

S/No.	Input Description	Project totals in percent
1	1= up to 28 days	60%
2	2= up to 35 days	36%
3	3 = up to 42 days	0%
4	4= up to 49 days	0%
5	5= up to 56 days	0%
6	6= up to 63 days	0%
7	7= up to 70 days	0%
8	8= up to 77 days	0%
9	9= up to 84 days	4%

Project feasibility (pre-construction) factor input data was obtained by checking the special conditions of contract. If there was a statement such as: *'conceptual drawings have been included here for purposes of tendering only; Detailed design drawings will be made available to the contractor after a detailed design has been completed and agreed with the client, contractor and consultant'* then the works were awarded before complettion of the design making the project feasibility below satisfactory. Other items giving an insight into prefeasibility included unnecessary lump sum pay items and variations exceeding 20 percent of the contract sum. The breakdown of the input data is shown in Figure 5.6.

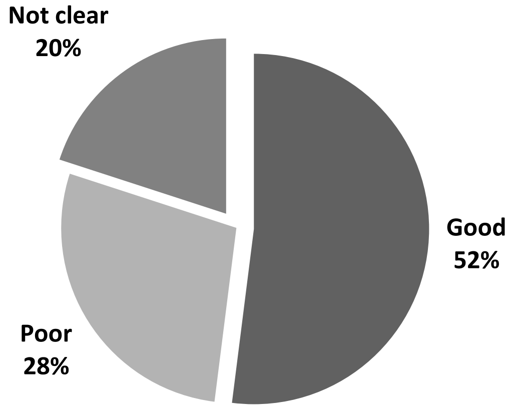


Figure 5.6: Breakdown of project feasibility data input

Information on 20 percent of the projects was not clear and could not be used in the training.

The consumer price index (CPI) was used in the determination of the input nodes for escalation at 2009 weights. Input data for escalation is shown in Table 5.5.

Table 5.5: Input data for escalation

S/No.	Input Description	Project totals in percent
1	1 = 0%	32%
2	2 = 5%	0%
3	3 = 10%	12%
4	4 = 15%	8%
5	5 = 20%	32%
6	6 = 25%	0%
7	7 = 30%	4%
8	8 = above 35%	12%

Input for materials availability was 1 indicating available locally for all projects.

The input for the country corruption profile factor used the Corruption Perception Index (CPI[1]). The input was 4 indicating corrupt for all projects.

Political environment input is shown in Figure 5.7.

Figure 5.7: Breakdown of the political environment input nodes

5.3 Kohonen architecture

The Kohonen architecture was considered appropriate because it is unsupervised and has the ability to learn without being shown correct outputs in sample patterns. This network is able to separate data into a specified number of categories. The Kohonen Self Organizing Map network contains only two layers: input and output layers which have one neuron for each possible category. The eight factors with associated input nodes of 254 projects were fed into the neural network.

5.3.1 Training criteria

i. Pattern selection

Rotation as opposed to Random was used. Rotation selects training patterns in order and use when like training patterns are dispersed evenly through the training set (Ward Systems, 2014). Random chooses the training patterns randomly, although it does not guarantee that every pattern will be chosen an equal number of times. The random number generator usually does not select all of the patterns during a single epoch, and will select some patterns multiple times (Ward Systems, 2014).

ii. Distance metric

Kohonen networks work by clustering patterns based on their distance from each other. In *Vanilla or Euclidean* distance metrics, the output of the network is the square of the distance between the pattern and the weight vector for that neuron, therefore the winner is the neuron with the minimum activation. *Normalised* takes arrays which are linear multiples of one another into the same normalised array Normalized distance metrics were used as the values for all of the inputs were in the same range. Ward Systems (2014) advised against using normalised distance as it is not usually the preferred method.

iii. Missing values

Missing Values were set to be considered as error conditions as opposed to zeros or minimum values. The selected training criteria are shown in Figure 5.8.

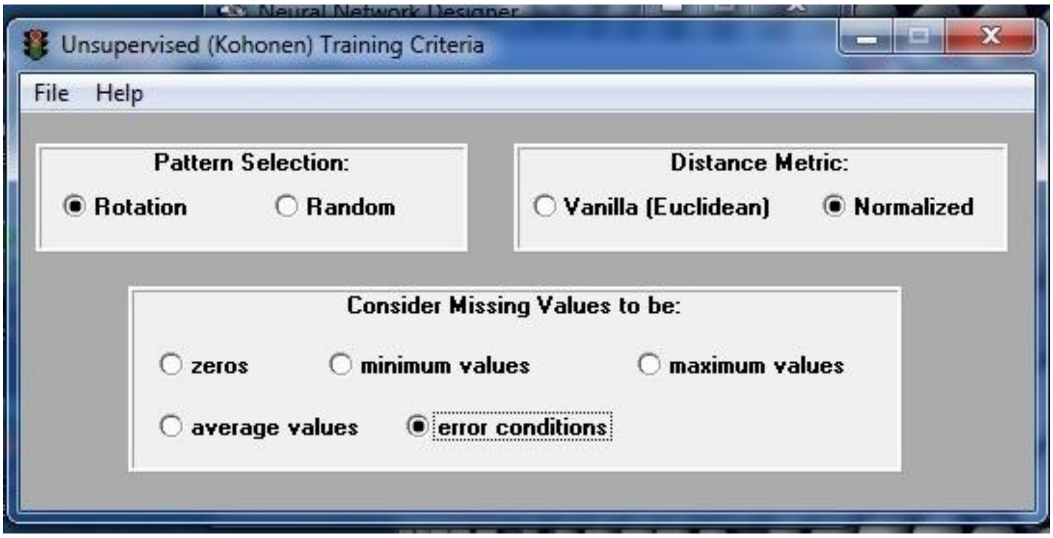
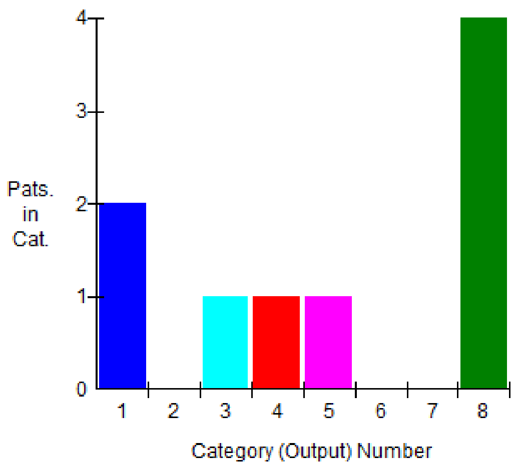


Figure 5.8: Snapshot of Kohonen training criteria
(After Ward, 2014)

The 8 factors were analysed. The training epochs were increased steadily from 1000, 5000, 10,000 and 50,000. The results after 10,000 epochs remained the same. The Kohonen Self Organizing Map network was able to separate data patterns as shown in Figure 5.9.



where:
1 = Contractor capacity
2 = Project Location
3 = Period of honouring payment
4 = Project feasibility
5 = Cost escalation
6 = Materials availability
7 = Country corruption profile
8 = Political environment

Figure 5.9: Graphical representation of neural network output

Figure 5.9 shows that political environment had the highest ration followed by contractor capacity. Period of honouring payment, Project feasibility and Cost escalation exhibited the same ratio and Project Location, Materials availability and Country corruption profile did not exhibit any trend.

5.3.2 Findings

The resulting ratio of the factors, namely, political environment, contractor capacity, period of honouring payments, project feasibility and escalation was 4:2:1:1:1. Therefore political environment was 44 percent of the unit rate followed by contractor capacity at 22 percent and period of honouring payment, project feasibility and cost escalation each at 11 percent. Three categories were unused namely: project location; material availability; and country corruption profile indicating that they had minimal impact on unit cost. This could be attributed to the rather constant figures of the factors. For instance, the CPI[1] was the same for all projects because the CPI[1] changes annually and Zambia has been in the same range for the past 5 years. The variation in distance of the sample projects was not high and material availability was normal without severe shortages.

From the trained data, source code was generated which was incorporated into the UCEM. The source code is shown in Appendix B. An example of the breakdown of the neural network factor output is shown in Table 5.6.

Table 5.6: Sample neural network output weights

S/No.	Description	Neural network output as %
1	Contractor Capacity:	0.4574782
2	Project Location:	0.4107191
3	Period of honouring payment:	0.4558006
4	Project Feasibility:	0.6888964
5	Escalation:	1.194833
6	Materials Availability:	1.7354806
7	Country corruption profile:	2.3342755
8	Political environment:	2.6137975

The neural network output depends on the selection made for each factor. These are not constant and the percentage changes depending on the combination of factors.

5.4 Summary

Chapter Five described how the input nodes for the various factors were derived. In addition, the results from the neural network were presented. Details of the neural network architecture used and training criteria adopted were presented. The Kohonen self-organizing map network predicted that political environment accounted for 44 percent of the unit rate followed by contractor capacity at 22 percent and period of honouring payments, project feasibility and escalation each at 11 percent. Project location, material availability and country corruption profile had minimal impact on the unit cost from the training data provided. Chapter Six focuses on building up rates from first principles to establish the base rate. The base rate in combination with the predicted neural network cost factors ultimately formed the study unit rate.

Chapter Six: Base Rate Computations

6.1 Introduction

Chapter Five described how the input nodes for the eight factors were derived and used in the neural network. The results of the neural network training revealed Zambian road sector economic strata. The neural network predicted that the political environment accounted for 44 percent of the unit rate followed by contractor capacity at 22 percent and period of honouring payments, project feasibility and escalation each at 11 percent. Project location, material availability and corruption perception index had minimal impact on the unit cost from the training data provided. This chapter focuses on building up rates from first principles by establishing the direct labour, material and plant and equipment costs combination for 854 work activities to form the base rate. The base rate integrated with the predicted neural network cost factors ultimately formed the study unit rate.

6.2 Method of measurement

There are various systems for building up unit rates in use in Zambia by both road sector consultants and contractors. Both consultants and contractors have developed their own databases of unit rates from past contracts. Some contractors and consultants build up rates from first principals using crew-mixes and productivity rates while others use historical rates coupled with consumer price indices as adjustment factors. It has been established that the choice of method or system is mainly dependent on individual and company preferences as well as the individuals' experience. Figure 6.1 illustrates the distribution of local cost estimation practices in Zambia.

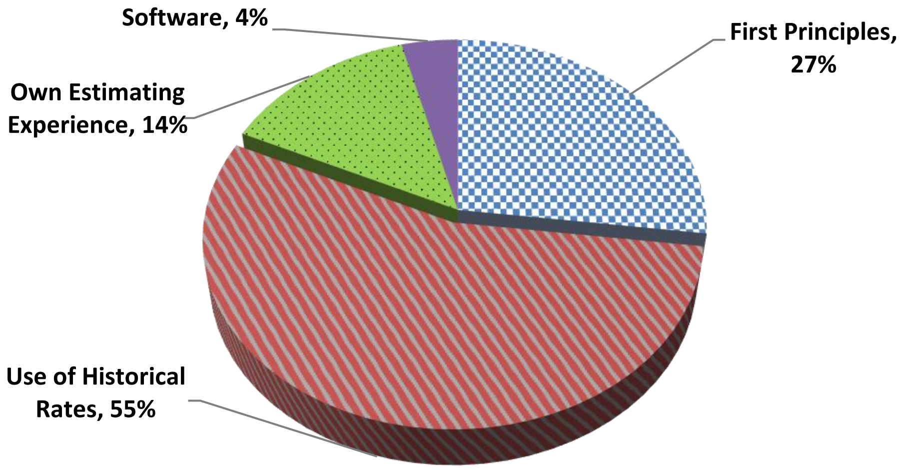


Figure 6.1: Distribution of cost estimation methods among practitioners

From the questionnaire survey, it was established that 55 percent of respondents use historical rates compared to 27 percent who build up rates from first principles. This concurs with the study carried out by Mashilipa (2004) where it was revealed that the most common method was the use of rates based on past contracts with an allowance for inflation followed by building up of unit rates from first principles and finally the use of a computer software. Holroyd (2000) stated that even though the building up of unit rates from first principles varied among contractors, if done correctly, the differences were more cosmetic than fundamental.

The unit rate activities are based on the standard Bills of Quantities template used in the Zambian road sector. The method of measurement is based on the Southern Africa Transport and Communications Commission (SATCC) Draft Standard Specifications for Road and Bridge Works – September 1998 (Re-printed July 2001) subject to variances specific to the Zambian road sector. The pay items and coding are organized into the seven main SATCC categories namely: General; Drainage; Earthworks and Pavement Layers of Gravel or Crushed Stone; Asphalt Pavements and Seals; Ancillary Works; Structures; and Testing and Quality Control. The work items hierarchical coding is shown in Table 6.1.

Table 6.1: Hierarchical structure of measurement items

LEVEL 1 CATEGORY	LEVEL 2 SERIES HEADING	LEVEL 3 PAY ITEM CODE
SERIES 1000: GENERAL	**1100:** Definitions and terms	No pay items
	1200: General requirements and provisions	No pay items
	1300: Contractor's establishment on site and general obligations	13.01
	1400: Housing, offices and laboratories for the Engineers' site personnel	14.01 – 14.16
	1500: Accommodation of traffic	15.01 - 15.12
	1600: Overhaul	16.01 – 16.02
	1700: Clearing and grubbing	17.01 – 17.03
SERIES 2000: DRAINAGE	**2100:** Drains	21.01 – 21.19
	2200: Prefabricated culverts	22.01 – 22.28
	2300: Concrete kerbing, concrete channelling, chutes and downpipes, and concrete linings for open drains	23.01 – 23.15
	2400: Asphalt and concrete berms	24.01 – 24.04
	2500: Pitching, stonework and protection against erosion	25.01 – 25.07
	2600: Gabions	26.01 – 26.04
SERIES 3000: EARTHWORKS AND PAVEMENT LAYERS OF GRAVEL OR CRUSHED STONE	**3100:** Borrow materials	31.01 – 31.03
	3200: Selection, stockpiling and breaking down the material from borrow pits and cuttings, and placing and compacting the gravel layers	32.01 – 32.06
	3300: Mass earthworks	33.01 – 33.13
	3400: Pavement layers of gravel material	34.01 – 33.10
	3500: Stabilisation	35.01 – 35.05
	3600: Crushed stone base	36.01 – 36.04
	3700: Waterbound macadam base	37.01 – 37.03
	3800: Breaking up existing pavement layers	38.01 – 33.15
SERIES 4000: ASPHALT PAVEMENTS AND SEALS	**4100:** Prime coat	41.01 – 41.03
	4200: Asphalt base and surfacing	42.01 – 42.07
	4300: Materials and general requirements for seals	43.01 – 43.03
	4400: Single seals	44.01 – 44.07
	4500: Double seals	45.01 – 45.06
	4600: Single seal with slurry (Cape seal)	46.01 – 46.06
	4700: Sand seals	47.01 – 47.02
	4800: Surfacing of bridge decks	48.01
	4900: Treatment of surface defects, patching, repairing edge breaks and crack sealing	49.01 – 49.15
SERIES 5000: ANCILLARY ROADWORKS	**5100:** Guide blocks	51.01 – 51.02
	5200: Guardrails	52.01 – 52.12
	5300: Fencing	53.01 – 53.08
	5400: Road signs	54.01 – 54.09
	5500: Road markings	55.01 – 55.09
	5600: Cattle grids	56.01 – 56.02
	5700: Landscaping and planting plants	57.01 – 57.11
	5800: Finishing the road and road reserve and treating old roads	58.01 – 58.02

LEVEL 1 CATEGORY	LEVEL 2 SERIES HEADING	LEVEL 3 PAY ITEM CODE
	5900: Painting	59.01
SERIES 6000: STRUCTURES	**6100:** Foundations for structures	61.01 – 61.50
	6200: Falsework, formwork and concrete finish	62.01 – 62.09
	6300: Steel reinforcements for structures	63.01 – 63.03
	6400: Concrete for structures	64.01 – 64.06
	6500: Prestressing	65.01 – 65.03
	6600: No-fines concrete, joints, bearings, bolt groups for electrification, parapets and drainage for structures	66.01 – 66.26
	6700: Structural steelwork	67.01 – 67.03
	6800: Construction tolerances for structures	No pay items
SERIES 7000: TESTING AND QUALITY CONTROL	**7100:** Testing material and workmanship	71.01 – 71.03
	7200: Quality control	No pay items

The coding continues beyond level 3. Level 4 coding is alphabetical using lower case alphabet letters. Level 5 is numbered sequentially using roman numerals.
Table 6.2 shows the summary of pay items per series category of works.

Table 6.2: Summary of pay items per series category of works

Series Category	Description	No. of pay items	Pay items with lump sum unit
Series 1000:	General	129	25
Series 2000:	Drainage	134	6
Series 3000:	Earthworks And Pavement Layers of Gravel or Crushed Stone	199	0
Series 4000:	Asphalt Pavements And Seals	145	2
Series 5000:	Ancillary Roadworks	162	2
Series 6000:	Structures	170	13
Series 7000:	Testing And Quality Control	5	2
Total		**944**	**50**

Table 6.2 shows that there are 944 pay items from the SATCC Standard Specifications. Of these, 50 are lump sum items and 50 percent of them fall under series 1000 which deals with preliminary and general items specifying how a project will be mobilized. Even with a good database, items that are bid lump sum are difficult to price as they vary from project to project. There is usually a percentage on the lump sum item as a pay item. For this study, lump sums and their associated percentage allowance items were left out, therefore, only 854 rates were built up.

6.3 Unit cost configuration

Road works consist of various work items that are aggregated into a work package. Base rate is the build up from first principles incorporating all direct input costs for the execution of each work item. Schematically the base rate calculation is shown in Figure 6.2.

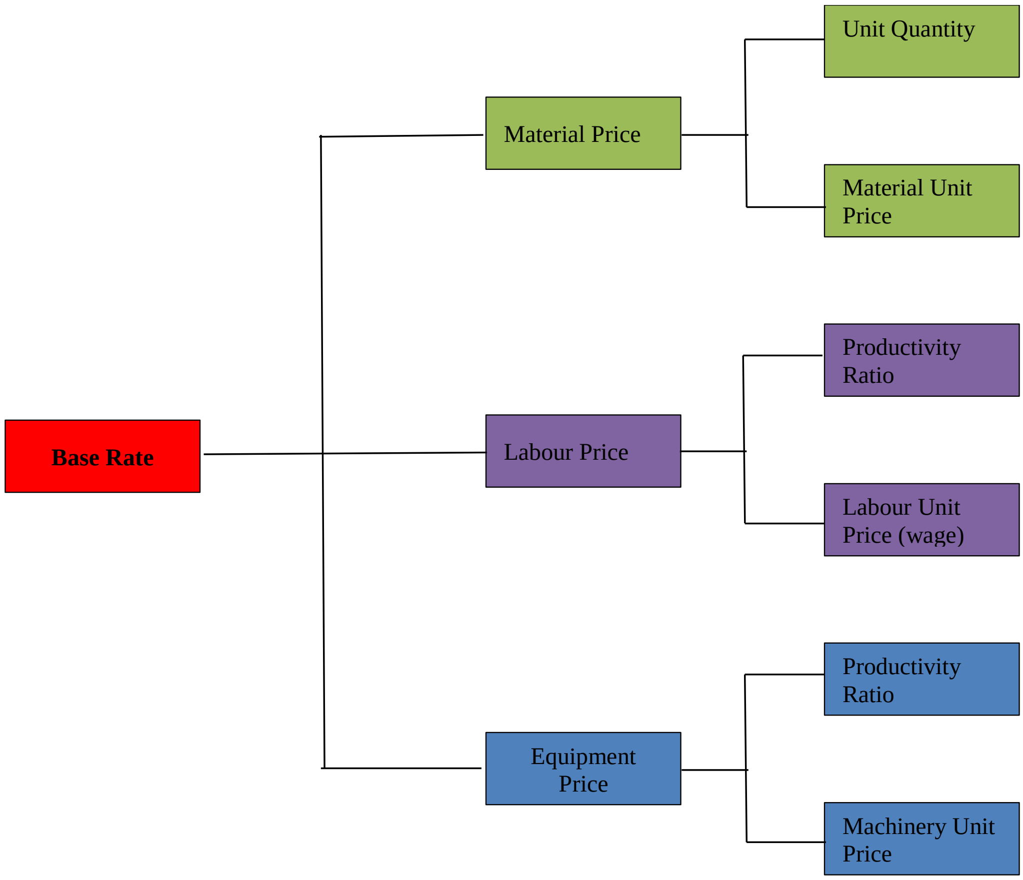


Figure 6.2: Schematic view of base rate calculation
(After Ministry of Roads, 2011)

Material, labour and machinery unit prices within the rates have been built up to derive an 'all-in-rate'.

6.3.1 All-in-labour rate

The all-in-labour rates were developed based on the Association of Building & Civil Engineering contractors (ABCEC) and National Union of Building, Engineering and General Workers (NUBEGW) Joint Industrial Council Collective Agreement (2014 - 2015) (ABCEC, 2013). From the basic wage rate determined by the unions, benefits such as holiday pay, service pay, funeral benefit, protective clothing, medical, tool, lunch and transport allowances are added to come up with an 'all-in-labour rate'. The detailed calculations are shown in Appendix C. A copy of the Joint Industrial Council Collective Agreement (2014 - 2015) which details the conditions of employment of different categories of labour in the ZCI is attached as Appendix D. The all-in-labour rates were then used in crew gang mixes for each work item. The calculated all-in-labour rates are shown in Table 6.3.

Table 6.3: All-in-labour rates

S/No.	Position	ABCEC Basic Wage (K/hr)	All-in-Labour Rate (K/hr)	Existing labour rates - 2014 (K/hr)
1	Labourer	3.97	12.12	4.20
2	Skilled Labourer	5.61	15.32	7.50
3	Equipment Operator	5.79	15.74	20.00
4	Foreman	6.10	16.34	30.00
5	Licensed Driver Gen. Purpose vehicle	5.17	14.54	-
6	Security Guard/Watchman	4.97	13.75	-

Table 6.3 shows an all-in-labour rate of approximately 300 percent of the basic wage. The existing rates show a lower rate for a general unskilled worker and a higher rate for a foreman. This could be attributed to non-provision of some of the conditions of service to general workers such as medical insurance. This is further exacerbated by ignorance of the conditions of service by the general workers. In contrast, foremen were provided with all the conditions of service and incentives. Contractors have defended their positions by stating that general workers were contract based and more attention was placed on foremen who were part of permanent staff.

6.3.2 All-in-material price

Materials include those permanently incorporated in the final work. The built-up rate allows for delivery charges of the material to the site. Discounts obtainable by the contractor have not been included because they vary depending on the contractor's standing, the potential size of the order and the supplier's eagerness (Spon's, 2014). Discounts on materials also vary between raw and manufactured goods. For instance timber attracts a low discount compared to manufactured goods where the room for bargaining is much greater. But Spon's (2014) stated that high demand for a product at the time of pricing could dramatically reduce the potential discount. The list inserted as Appendix E shows major materials commonly used in road construction. The prices are the prevailing rates as at 30th June 2014.The allowance for wastage of material on site was taken care of in the base rate calculations. Major construction materials in the Zambian road sector to price correctly identified below.

i. Asphalt products

Asphalt-based materials are used in gravel road upgrading, paved road maintenance, re-surfacing, chip sealing and pothole patching. Asphalt product costs have increased at a much higher rate than crude oil (AGC, 2008). Asphalt is produced as a by-product when crude oil is refined to make diesel, and other lighter fuels. Refineries are now opting for a refinement process that extracts even more of these lighter fuels from each barrel of crude. But this process produces a by-product which is solid fuel called petcoke, a material somewhat similar to coal, but is not useful to the asphalt industry (AGC, 2008). With less asphalt being produced, it is anticipated that there will be a shortage of asphalt resulting in price increases. AGC (2008) reported that in many Washington State counties, both solid hot mix and liquid asphalt prices have increased by about 135 percent since 2004.

ii. Fuel

Diesel is used to power earthmoving and other heavy construction equipment vehicles such as dump trucks, concrete mixers and pumps, and tower cranes. Diesel costs and fuel surcharges also work their way into the prices of many materials that require fuel to move through the production process. For instance, quarrying, crushing, sorting and delivery of aggregate and sand take large amounts of diesel fuel. Diesel prices have been extremely volatile over the past several years. Since December 2003, the price for diesel fuel soared 186 percent, the most of any major construction input (AGC, 2008). In Zambia, fuel prices were more expensive the further away one was from the oil refinery in Ndola. This trend was reversed in 2011 when the Government of Zambia (GRZ) introduced a policy making fuel prices uniform throughout the country.

iii. Steel

The current consumption of iron and steel in Zambia stands at 50,000 to 70,000 tonnes per annum (UMCIL, 2015) as an imported product. The bulk of the import is consumed in building and construction, manufacturing, engineering and mining. The cost of imported steel as at 2014 was US$ 1,200/tonne (UMCIL, 2015). There was limited information regarding steel price trends in Zambia for the period 2009 to 2014. It was hoped that once the two steel plants, Kafue Steel owned by Universal Mining & Chemical Industries Ltd and Good Time Steel, a Chinese company, commenced full production, the cost of steel would reduce.

iv. Cement

Cement is produced locally in Zambia. But comparisons presented in Chapter 5 showed that Zambian ex-factory prices were substantially higher than in other neighbouring countries, and at times close to double those in South Africa, the lowest priced country (Mbongwe et al., 2014). The assumption therefore was that the unit rates of the Zambian road sector were expected to be higher than those in the region.

Figure 6.3 shows the price trend of cement, bitumen and diesel during the period 2009 - 2014.

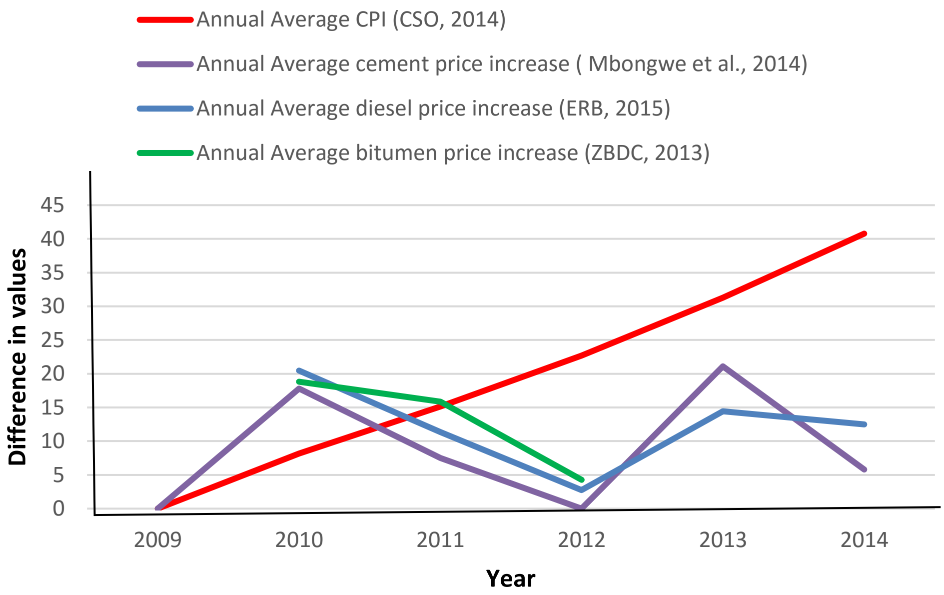


Figure 6.3: Price trend of cement, bitumen and diesel during 2009 - 2014

When compared with the consumer price index (CPI), the three construction materials show a dip in 2012. The construction material trend is more reflective of the activity of the industry than the CPI. It is therefore recommended that the Zambian road sector should do away with using the CPI and instead come up with construction specific indices.

6.3.3 All-in-equipment rate

Construction equipment and tools form a major part of the base unit rate, i.e. direct cost. There are various methods of calculating ownership and operating costs but the common ones are: the caterpillar method; Association of General Contractors of America (AGC) method; the Corps of Engineers method; and the Peurifoy/Schexnayder method. Literature indicates that the AGC method yields the highest rates while Corp of Engineers method is the lowest. The caterpillar and Peurifoy/Schexnayder methods fall somewhere in the middle. The choice of method is mainly based on a company's preference and business strategy. In this study, the Caterpillar Method was adopted mainly because it was developed by renowned equipment manufacturers and seems to provide a fair estimate of costs. It is noteworthy also that the other methods are easier to compute and update only when the country has well developed indices which is not the case with Zambia.

The equipment costs include not only purchase or lease price, but also operating costs for equipment under normal use. The operating costs include parts and labour for routine servicing, such as repair and replacement of pumps and filters. Normal operating expendables such as fuel, lubricants, tires, and electricity (where applicable), were also included. Equipment costs were obtained from industry sources locally and from international suppliers, dealers, manufacturers, and distributors. Equipment costs do not include operators' wages, nor do they include the cost to move equipment to or from a project site during mobilization or demobilization activities. The detailed calculations using the caterpillar method are shown in Appendix F. The rates obtained were then used for each BoQ activity.

6.4 Base unit rate calculation sample

Expected outputs of various types of civil engineering operations and their listed person-hours were obtained and used in formulating unit rates from first principles.

6.4.1 MC 30 cut back bitumen

For instance, the basic rate for pay item 41.01(c) Asphalt and Pavement seals: Prime coat MC 30 Cut back bitumen was calculated using outputs and combination of labour, material and equipment shown in Table 6.4.

Table 6.4: Example of base rate calculation from first principles

Pay item	Description	Unit	Qty	Rate ZMW	Total ZMW
41.01 (c)	**MC 30 cut back bitumen**				
	Unit = litre				

Pay item	Description	Unit	Qty	Rate ZMW	Total ZMW
	Taking output = 2000 litres				
	1. Labour				
	Foreman	day	0.08	131.36	10.5088
	Labourer	day	2	96.96	193.92
	Equipment operator	hour	2	14.64	29.28
	2. Machinery				
	Mechanical broom @ 1250 m2 per hour	hour	2.8	53.49	149.772
	Air compressor 250 cfm	hour	2.8	63.82	178.696
	Bitumen pressure distributor @ 1750 m2 per hour	hour	2	160.86	321.72
	Water tanker 6000L capacity @ 1 trip per hour	hour	1	116.58	116.58
	3. Material				
	Cut back bitumen MC30 *Note: 1kg = 1Litre add 10% loss*	L	2200	7.2	15840
	Cost of water	L	6000	3.17	19020
	Note: 1kg = 1Litre add 10% loss margin				35831.197
	4. Total (1+2+3)/output				**17.9302384**

From Table 6.4 the calculated rate for MC 30 cut back bitumen was K17.93. Another demonstration example is the overhaul and restricted haul calculations as these are normally contentious item on a road project.

6.4.2 Overhaul calculation

Overhaul has been calculated as shown in Table 6.5.

Table 6.5: Overhaul calculation from first principles

16.02	Overhaul on material hauled in excess of 1.0 km (ordinary overhaul)				
	Unit = m3.km				
	Taking output 12m3 (20 tonnes) load and distance of 1 km = 12m3-km				
	Unsurfaced Gravelled Road				
	Speed with load is 20 km / hour (3min/km)				
	Speed for empty return trip is 30 km / hour(2min/km)				
	1) Labour	**Unit**	**Qty**	**Rate ZMW**	**Total ZMW**
	Equipment operator (onward trip)	hr	0.05	15.76	0.788
	Equipment operator (return trip)	hr	0.033333	15.76	0.525333
					1.313333
	2) Machinery				
	Tipper 20 tonnes capacity				
	Time taken for onward haulage with load for 1km is	hour	0.05	178.56	8.928
	Time taken for empty return trip	hour	0.033333	178.56	5.952
	cost for 12m3-km (1+2)				16.19333
	Rate per m3-km				**1.34944**
	Note: ZMW178.56 is the hourly rate for20T truck and ZMW15.76 is the hourly rate for an equipment operator				

Items affected by the overhaul have been shown separately in Table 6.6.

Table 6.6: Items affected by overhaul

Pay item	Description	Unit
21.04	Impermeable backfilling to subsoil drainage systems	m^3
22.12	**Removing existing concrete**	
	(a) Plain concrete	m^3
	(b) Reinforced concrete	m^3
22.13	Removing and re-laying existing pipes (size and type of bedding indicated)	m
22.14	Removing and stacking existing prefabricated culverts (all sizes)	m
26.01	**Foundation trench excavation and backfilling**	
	(a) in solid rock (material which require blasting)	m^3
	(b) in soft material (and any other materials)	m^3
3400	**PAVEMENT LAYERS OF GRAVEL MATERIAL**	
34.01	**Pavement layers constructed from gravel taken from cut or borrow, including free-haul up to 1.0 km:**	
	(a) Gravel selected layer compacted to :	
	(i) 90% of modified AASHTO density (specify compacted layer thickness)	m^3
	(ii) 93% of modified AASHTO density (specify compacted layer thickness)	m^3
	(iii) 95% of modified AASHTO density (specify compacted layer thickness)	m^3
	(b) Sand selected layer compacted to 100% of modified AASHTO density (fraction sand< 0.075 mm less than 20%) (specify compacted layer thickness)	m^3
	(c) Gravel sub base (unstabilised gravel) compacted to:	
	(i) 95% of modified AASHTO density (specify compacted layer thickness)	m^3
	(ii) 97% of modified AASHTO density (specify compacted layer thickness	m^3
	(d) Gravel sub base (chemically stabilised material) compacted to:	
	(i) 95% of modified AASHTO density (specify compacted layer thickness)	m^3
	(ii) 97% of modified AASHTO density (specify compacted layer thickness)	m^3
	(e) Gravel base (unstabilised gravel) compacted to:	
	(i) 98% of modified AASHTO density (specify compacted layer thickness)	m^3
	(ii) 100% of modified AASHTO density (specify compacted layer thickness)	m^3
	(f) Gravel base (chemically stabilised material) compacted to:	
	(i) 97% of modified AASHTO density (specify compacted layer thickness)	m^3
	(ii) 98% of modified AASHTO density (specify compacted layer thickness)	m^3
	(g) Gravel shoulders compacted to :	
	(i) 93% of modified AASHTO density (specify compacted layer thickness)	m^3
	(ii) 95% of modified AASHTO density (specify compacted layer thickness)	m^3
	(h) Gravel wearing course compacted to :	
	(i) 93% of modified AASHTO density (specify compacted layer thickness)	m^3
	(ii) 95% of modified AASHTO density (specify compacted layer thickness)	m^3
57.03	**Preparing the areas for grassing:**	
	(c) Top soiling within the road reserve, where the following materials are used:	
	(i) Topsoil obtained from within the road reserve or borrow areas (free-haul 1.0 km)	m^3
	(ii) Topsoil obtained from other sources by the Contractor (including all haul)	m^3
	(d) Top soiling of borrow pits by using topsoil obtained from borrow areas or from the road reserve (free-haul 1.0 km)	m^3
61.04	**Backfill to excavations utilising:**	
	(a) Material from the excavation	m^3
	(b) Imported material	m^3
	(c) Soil cement	m^3

The Unit Cost Estimation Model (UCEM) has provision for changing overhaul distance. The SATCC specifications provide for a free haul distance of 1 km. Based on the overhaul calculations, if the free haul distance is varied to 10 km all the items in Table 6.6 are increased by ZMW12.15.

6.4.3 Restricted haul

Restricted haul has been calculated as shown in Table 6.7.

Table 6.7: Restricted haul calculation from first principles

16.01	Overhaul on material hauled in excess of a free-haul distance of 0.5 km, for haul up to or through 1.0 km (restricted overhaul)				
	Unit = m3				
	Output of 30m3				
	1) Labour	**Unit**	**Qty**	**Rate ZMW**	**Total ZMW**
	Equipment operator	hour	6	15.76	94.56
					94.56
	Grading speed 6 km / hour (10min/km)				
	2) Machinery				
	CAT 14 Motor grader				
	Time taken for grading is	hour	6	295.73	1774.38
	cost for 30m3 (1+2)				1868.94
	Rate per m3				**7.27214**
	Note: ZMW295.73 is the hourly rate for grader				

Items affected by the restricted haul have been shown separately in Table 6.8.

Table 6.8: Items affected by restricted haul

Pay item	Description	Unit
33.01	**Cut and borrow to fill, including free-haul up to 0.5 km:**	
	(a) Gravel material in compacted layer thicknesses of 200 mm and less:	
	(i) Compacted to 90% of modified AASHTO density	m^3
	(ii) Compacted to 93% of modified AASHTO density	m^3
	(iii) Twelve roller passes compaction	m^3
	(b) Gravel material in compacted layer thicknesses from 200 mm to 500 mm:	
	(i) Compacted to 90% of modified AASHTO density	m^3
	(ii) Compacted to 93% of modified AASHTO density	m^3
	(iii) Twelve roller passes compaction	m^3
	(c) Rock fill (as specified in Sub clause 3209(c))	m^3
	(d) Rock protection at the toes of fills	m^3
	(e) Pioneer layer	m^3
	(f) Sand filter blanket	m^3
33.02	**Sand fills (as described in Clause 3302, including free-haul up to 0.5 km):**	
	(a) Non-plastic sand with up to 20% passing through the 0.075 mm sieve, compacted to 100% of modified AASHTO density	m^3
	(b) Non-plastic sand with more than 20% passing through the 0.075 mm sieve, compacted to 95% of modified AASHTO density	m^3
33.04	**Cut to spoil, including free-haul up to 0.5 km. Material obtained from:**	
	(a) Soft excavation	m^3
	(b) Intermediate excavation	m^3
	(c) Hard excavation	m^3
	(d) Boulder excavation Class A	m^3
	(e) Boulder excavation Class B	m^3
33.07	**Removal of unsuitable material (including free-haul of 0.5 km):**	
	(a) In layer thicknesses of 200 mm and less:	
	(i) Stable material	m^3
	(ii) Unstable material	m^3
	(b) In layer thicknesses exceeding 200 mm:	
	(i) Stable material	m^3
	(ii) Unstable material	m^3

The effect of restricted haul on linked items in Table 6.8 varies from free haul. Restricted haul only affects the linked items when it is not allowed. If the haul is allowed, then there is no effect.

Calculations of all 854 pay items included in the model were done. Detailed unit rate calculations from first principles of all items are not shown, but the derived rates for series 3000 are indicated as Appendix G. The rates presented are ‘bare’ or basic without any overhead or profit.

6.5 Summary

Chapter Six focused on building up unit rates from first principles to establish the base rate. The base rate calculations considered direct labour, material and plant and equipment costs based on productivity rates of the various work items. Contentious items such as overhaul and restricted haul were calculated and their effects on related pay items highlighted. Chapter Seven presents the development of UCEM. It focuses on how the base rate in combination with the predicted neural network cost factors ultimately forms the unit rate established by the UCEM. It further presents the validation of UCEM with data from other local projects and those from SADC countries.

Chapter Seven: Unit Cost Estimation Model

7.1 Introduction

Chapter Six established the base rate for 854 pay items in the SATCC specifications. Base rate calculations considered direct labour, materials, and plant and equipment costs based on productivity rates of the various work items. This chapter presents the development of the Unit Cost Estimation Model (UCEM). It focuses on how the base rates in combination with the predicted neural network cost factors ultimately formed the unit rates established by the UCEM. It further presents the validation of the UCEM with data from other projects in the Zambian road sector that were not part of the neural network training. In addition, the model was validated with project data from Southern African Development Community (SADC) countries.

7.2 Technical specifications

The model is computer based and was developed with C# 5.0 (2012) programming language using .NET Framework 4.0 and MySQL 5 as the database engine. The front end is HTML 5, CSS 3, and JavaScript. The model also uses popular web technologies and frameworks such JQuery and Bootstrap. To improve on performance and loading times, the model makes uses of AJAX. AJAX is the art of exchanging data with a server, and allows certain parts of a website to update without refreshing the entire page. This behaviour is pronounced when expanding and collapsing items on Bills of Quantities (BoQs). The model is web based therefore it could be accessed from any browser such as Internet Explorer, Firefox, Chrome even from a tablet or mobile phone. The model has incorporated both quantitative and qualitative factors to produce a unit cost rate. The model outputs are the BoQ descriptions and pay items with their associated unit rates. If quantities are added the total is subjected to Value Added Tax (VAT) to reveal the project cost estimate. The flow chart of the model is shown in Figure 7.1.

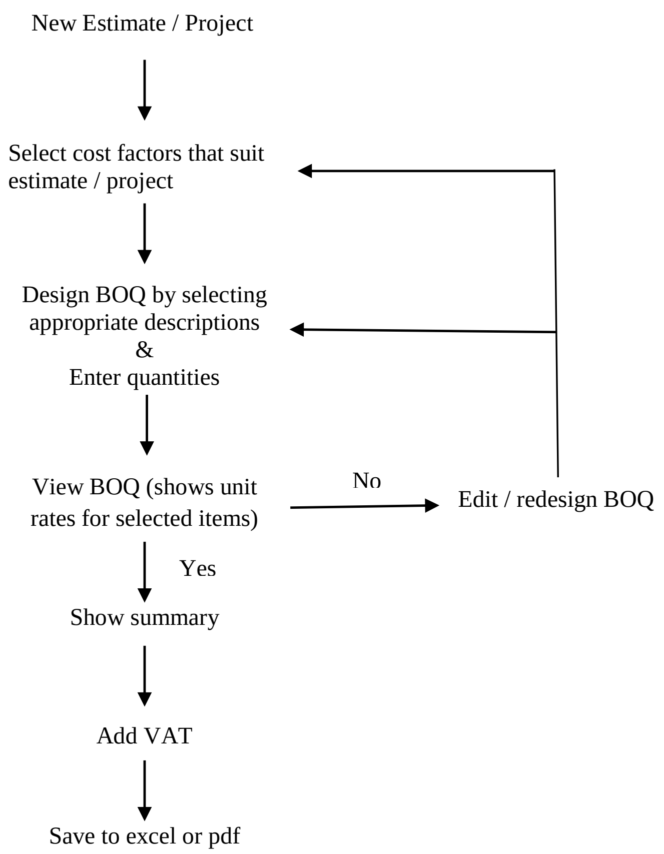


Figure 7.1: UCEM flowchart

The flowchart indicates steps taken to use the model. The quick start guide for the UCEM is shown in Appendix H.

7.2.1 Model functionality

It was essential that the model incorporated a minimum six functions which would be integrated to enhance functionality. The six requirements are shown in Figure 7.2.

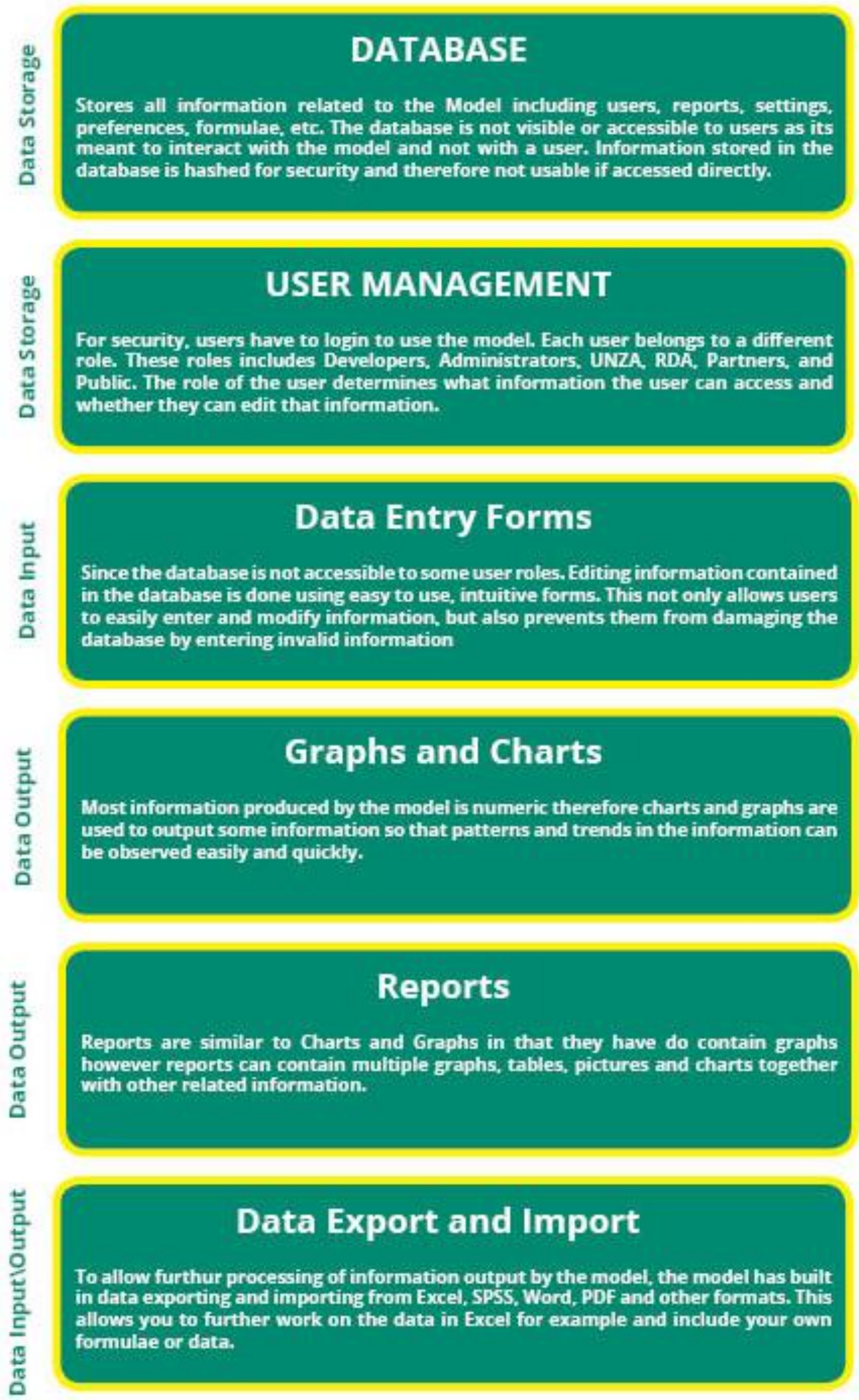


Figure 7.2: UCEM basic functions

The UCEM incorporates all functions indicated in Figure 7.2 and is able to:

i. store data;

ii. track users and changes;

iii. allow for user friendly input of data;

iv. allow for easy visualisation of output data;

v. generate reports; and

vi. import and export data.

7.3 Model development

The output of the model is the work item description with the corresponding unit cost. To achieve this various data had to be populated into the model.

7.3.1 Data population

i. Series

All the 944 pay items identified from the SATCC specifications were entered into the model as series items. The layout of the series or work items was similar to the BoQs. The series were not static, and new series' could be added. For instance, in the model, series 8000 was added to cater for daywork items. As construction methods change there would be need in future to add new methods of measurements. Therefore, a provision to customise the series by adding new pay items was made. There is also a provision to update existing series. The output for a series or work item was mandatory and required before a series could be saved. The output is the same as the productivity of the work item depending on the unit of measurement specified. The model provides for selection of work items affected by specified base calculations such as free haul and restricted haul. Remove is a feature provided to stop linking.

ii. Units

Each work item or BoQ description has a corresponding unit of measurement. The standard unit of measurement input is according to SATCC specifications which is metric. There is no feature for automatic conversion to imperial units of measurement. However, there is a provision to add new units to the existing list. The name for a unit is mandatory and requires to be provided before a unit can be saved.

iii. Currencies

As materials were from different sources, a feature for currency input has been provided. Apart from the local currency, international currencies such as the United States Dollar (US$), South African Rand and Malawian Kwacha have been incorporated. These currencies were included for model validation as well. There is a provision to add new currencies to the existing list. However, there is no internal link or conversion amongst the various currencies. The only conversion is to the local currency, the Zambian Kwacha. A code for currency input is mandatory and requires to be provided before a currency can be saved.

iv. Labour

Labour is one of the direct costs required for base rate calculations. Therefore, the input for all- in-labour build up is provided in the model. The model provides for updating, deleting or addition of any of the parameters. The model also provides for addition of new worker categories. The all-in-labour rate for the new worker category is calculated based on the labour built up formula in the model

v. Materials

Materials being one of the direct costs required for base rate calculations are fed into the model. The materials are divided into raw materials and hybrid materials. Raw materials are entered directly with no material build up formula. Hybrid materials such as cement mortar, reinforced or plain concrete and fog or slurry seals are calculated from raw materials inputs and are used in the build-up of other work items. The model provides for updating, deleting or addition of materials.

vi. Equipment

The caterpillar method formula for all-in-equipment rates was entered into the model. For equipment only, the purchase price, life of service in years, and utilization factor were required. The remaining fields are automatically calculated to derive the hourly rate. The model provides for updating, deleting or addition of machinery.

7.3.2 Base rate calculations

Specific labour, materials and machinery were then added to pay items to derive the base calculations using the Equation 7.1:

$$BR = \frac{\sum(L, M, EP)}{output}$$

Equation 7.1

where:

BR = base rate

L = labour

M = material

EP =equipment & plant

For instance, under pay item 17.01: Clearing and Grubbing where the unit = Hectare and output = 1 Hectare, Labour categories selected were Foreman with 0.160 days and unskilled Labourer with 4.000 days. There were no materials but one D6 Dozer at 10.000 hours under equipment and plant. The model then calculated the base rate based on the all-in-labour and equipment and plant rate.

7.3.3 Neural network cost factors

The eight input nodes were incorporated as labels with multiple list selection boxes on the user interface. The source code generated by NeuroShell2 was incorporated in the backend of the UCEM model. After selecting the project conditions from the cost factors, the neural network processed coefficients added to the base rate. Figure 7.3 shows a snapshot of the neural network factors on the user interface.

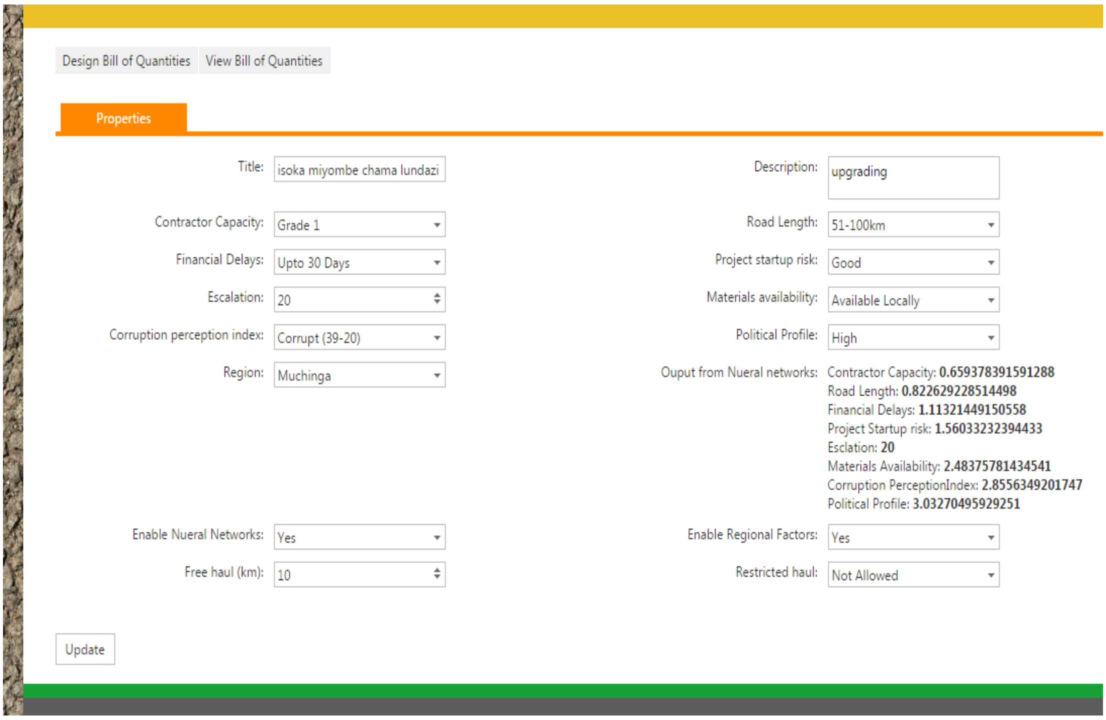


Figure 7.3: Snapshot of neural network cost factors

7.4 Validation of the model

Validation of the UCEM was done using a two-step process. Firstly, the model was validated locally using data from the Zambian road sector projects not utilised in the neural network training. The second step involved validating the model with project data from the three (3) SADC countries namely Malawi, South Africa and Zimbabwe.

The UCEM was validated using real system measurements followed by expert intuition for local validation and theoretical results analysis for regional validation.

7.4.1 Local validation

Locally the model was validated using five projects from the Zambian road sector. The criteria for selection of the projects were varying location; type of intervention; and not used in neural network training. Particulars of the selected projects are shown in Table 7.1.

Table 7.1: Project particulars

S/No	Project Description	Province	Distance	Type of Intervention	Year	Rate/Km
A	Isoka-Muyombe-Chama-Lundazi Road-Lot2 from D790-M14 [Chire River]	Muchinga	93km	Upgrading Double seal	09-2014	4,264,784.13
B	Bottom Road: Lot 2- From Chaaboboma Via Sinazeze to Sinazongwe	Southern	107.5km	Upgrading Double seal	09-2014	5,511,627.91
C	T004 [Great East Road] From Arcades to Airport Junction	Lusaka	10km	Rehabilitation Asphalt	02-2014	6,535,686.51
D	D153 from GER at Moono Police Check Point via Palabana to Road D151 at Chilyabale Basic School	Central	54km	Upgrading Double seal	11-2013	4,094,840.69
E	Vyamba-Chinakila Rd	Northern	43km	Periodic maintenance gravel	03-2015	1,195,096.89

From Table 7.1 all the projects are from different locations in Zambia. They have varying road lengths and incorporate the common types of intervention used in the Zambian road sector. This was necessary in determining whether the model was sensitive to varying cost factors. To ensure that the projects were subjected to the same costing environment, the tendering period was considered. Table 7.2 presents comparison of rates from the model to those of the projects from the BoQs

Table 7.2: Comparison of selected rates from the model to BoQ rates

Work description	Pay item code	Unit	Rate from Model	Project name from Table 7.2				
				A	**B**	**C**	**D**	**E**
Accommodating traffic and maintaining diversions *(The rate from the model is in km while the projects are reflecting rates per month)*	15.01	km	**1,363.64**	40,000.00	36,675.01	262,137.83	3,622.00	-
Shaping of diversions	15.02(a)	km	**9,265.38**	12,000.00	2,239.57	-	7,645.00	-
Gravelling and repair of diversions	B15.05	m3	**18.74**	12.00	8.44	-	50.00	-
Clearing and shaping existing open drains	21.02	m3	**15.31**	,-	1.71	151.33	17.00	-
Excavating in common material situated within the following depth ranges below the surface level: 0 m up to 1.5 m	22.01(a)(i)	m3	**12.03**	100.00	-	-	17.00	50.00
Concrete kerbing	23.01(a)	m	**57.00**	100.00	170.36	-	76.00	-
Soft excavation	33.04(a)	m3	**12.03**	400.00	6.13	-	17.00	-
95% of modified AASHTO density (specify compacted layer thickness)	34.01(c)(i)	m3	**95.62**	70.00	99.60	-	60.00	80.00
Ordinary Portland cement	35.02(a)	tonne	**1,350.00**	1.00	2,653.65	3,057.66	1,540.00	-
Prime coat MC-30 cut-back bitumen	41.01(c)	Litre	**13.98**	12.00	8.02	11.76	5.49	-
Double seals using 19.0 mm and 9.5 mm aggregate (state types of binders to be used)	45.01(a)	m2	**22.14**	24.00	35.95	-	-	-

7.4.2 Local validation findings

The neural network was turned off so that only the base rates were generated from the model. A number of work items were not considered because the units of measure had been modified. For example, the first item on accommodating traffic has been quoted monthly while the SATCC and UCEM unit of measure is in kilometres (km). Rates for series 5000 were not included in Table 7.2 because the rates varied due to non-standardisation of ancillary items. For instance, the Zambian road sector has no standard for kilometre and marker posts. Therefore, the BoQ rates represent varying sizes and specifications.

It was difficult to compare the rates from the model to those from the BoQ's. The rates among the projects varied widely. For instance, from Table 7.2 and pay Item 35.02(a), it is impossible to have a rate of K1.00 for project A when the price per tonne of cement from the manufacturer was K1,200.00. Another example is pay item 33.04(a) in soft excavation. The rate of K400.00 for project A could indicate labour based methods of excavation.

The varying rates could be attributed to contractors' costing strategies such as *front loading* where rates for activities that are scheduled early in the work programme are higher than those that come at the end. Another strategy is *quantity sensitivity*. Contractors tend to lower the rate of items with high quantities as compared to those with low quantities so that the tendered sum is competitive. The third strategy is *work activity probability*. In this case the contractor considers the chance of a work item being undertaken. For instance, in Project A pay Item 42.02, the contractor indicated an unreasonable low rate of K1.00 to supply, lay, and compact hot-mix asphalt 50 mm thick. Project A was a double seal road therefore, the contractor saw a low probability of executing that work hence the low rate. This goes back to the consultant to ensure that only work activities related to the project are included.

Without rate calculations from first principles and lack of an engineer's estimate, it would be difficult to justify any of the rates presented from real projects. This is the scenario pertaining in the Zambian road sector. For stakeholders to benefit from the UCEM, it is recommended that items such as road signs, marker posts, kilometre posts and guard rails be standardised.

7.4.3 Regional validation

Five (5) SADC countries namely: Botswana; Malawi; South Africa; Tanzania; and Zimbabwe were targeted for validation but only three responded favourably. Validation using real system measurements was achieved by travelling to these countries to collect physical data. The countries were selected because they employ the SATCC specifications on road projects and being in the same region it was assumed that the variation in construction methods would not be drastic. All-in-labour, material and machinery rates were collected and input into the model. The unit rates generated by the model were then compared to rates in the BoQs of existing road projects collected from the various countries. The visits targeted road authorities in each country. To ensure uniformity in collection of data, structured questions were prepared as shown in Appendix I. Information for the three countries that responded is summarised below.

i. Malawi

The purpose of Malawi Road Authority is to construct, rehabilitate and maintain public roads. The country has an approximately of 15,451 km of roads in total; of these, 4,038 km are paved and the remaining 11,413 km are unpaved. The sector handles a total annual project cost of approximately US$130 million. Historical rates are used during project identification and the engineers' estimates generated are within the accuracy of ±10. The foreign exchange rate during the time of data collection was at 1US$ = MK450. The description of the Malawi road sector is made in terms of: contractors; plant and equipment; materials availability and influential factors.

a) Contractors

There are approximately 250 contractors in the road sector in Malawi. These contractors are categorized into unlimited, medium and small. There are 70 percent foreign and 30 percent local contractors.

b) Plant and equipment

The plant and equipment for construction in Malawi is not readily available in the country, but that which is available is in satisfactory state. The ratio of owned to hired equipment in the country was not provided.

c) Materials

The availability of the road construction materials in the country is poor.

d) Cost factors

The Malawi Road Authority had shown that the cost factors that had the greatest influence on the unit cost were material shortages and source because the availability of materials in the country is poor due to topography and frequent fuel shortages.

ii. South Africa

The South African National Roads Agency Limited (SANRAL) is responsible for the management, maintenance and improvement of South Africa's national road network.

The road sector has a total road network of 750,000 km of which 158,000 km is paved and 592,000 km unpaved. The sector handles an approximate total annual road projects budget worth US$ 2,000 million. The South African road sector has official productivity rates which are published in various reports by the Construction Industry Development Board (CIDB). However, these are not used when adjudicating tenders, as tenders of registered CIDB contractors that qualify to tender for specific project are evaluated based on Price and Black Economic Empowerment (BEE). Engineer's estimates for projects are formulated from first principles during detail design stage. Historical rates are mostly used during project identification or concept stage. Estimates generated are within a ±10 to 20 percent range. At the time of data collection, the foreign exchange rate was at 1US$ = R11.50. The description of the South African road sector is made in terms of: contractors; plant and equipment; materials availability and influential factors.

a) Contractors

There are approximately 35,748 contractors in the road sector in CIDB Grade 1 to 9 of which 67 are large scale contractors in grade CIDB 9CE.Of these 98 percent are local contractors. Contractors belong to the South African Federation of Civil Engineering Contractors (SAFCEC). SAFCEC provides minimum conditions of work for their members which are legislated in South Africa.

b) Plant and equipment

The condition of plant and equipment required for road construction is fairly good and is readily available within the country. It was not clear on the ratio of owned to hired equipment as this detail was not available. In addition, build-up of rates for equipment was not provided as it was considered private and confidential by contractors, since this was what gave them the edge against the competition. Therefore, it was not clear which method is used to calculate all-in-equipment hourly rates.

c) Material

Almost all, about 98 percent, of road construction materials were readily available in the country.

d) Cost factors

SANRAL indicated that the cost factors which had the greatest impact on unit rates were: fuel; source of materials; and quality of project planning documentation. Source of material became a factor when the haulage distances which are affected by fuel prices were long. On the other hand, duration and project scope had the least influence on unit rates.

iii. Zimbabwe

There are 88,133 km of classified roads in Zimbabwe, 17,420 km of which are paved. About 5 percent of the network is classified as primary roads and has some of the most trafficked arterials that link Zimbabwe with its neighbours. Secondary roads account for 14 percent of the network. They link the main economic centres within the country, enabling internal movement of people and goods. The primary and secondary roads are collectively referred to as the trunk road system; they carry over 70 percent of the vehicular traffic, measured in vehicle kilometres, and they are managed by the Department of Roads (DoR). A little more than 70 percent of the network is made up of tertiary feeder and access roads that link rural areas to the secondary road network. These are managed by the District Development Fund (DDF) and by District Councils (DC). Tertiary access roads, together with the unclassified tracks, typically with traffic volumes below 50 vehicles per day, provide for the intra-rural access movements. The remaining 9 percent of the network comprise urban roads managed by urban councils.

The Zimbabwean road sector consists of the following institutional structure:

i. the Ministry of Transport, Communications and Infrastructural Development through the Department of Roads (DoR) serves as National Roads Authority;
ii. Rural District Councils and Urban Councils;
iii. The Zimbabwe National Road Administration (ZINARA) responsible for solicitation of funds from road users for the maintenance of existing road infrastructure; and
iv. a Road Fund to provide an adequate, stable, secure, and sustainable source of funds for the maintenance of the road network.

The Zimbabwean road sector has official productivity rates which are managed and kept by the Department of Roads. These productivity rates form the basis for the evaluation of tenders. Engineer’s estimates for projects are formulated from first principles, and in some cases from historical rates with the application of adjustment factors. Estimates generated are within a ±10 to 15 percent range in terms of accuracy. At the time of data collection, the currency in use was United States Dollar but the exchange rate was 1US$ = ZM$ 6.98.

It is noted that at the time of data collection the country was still recovering from an economic crisis which led to the change of the official currency from Zimbabwean Dollar to United States Dollars. This made the department of roads not to provide enough information on priced bill of quantities for completed projects, since works priced in the later currency were still ongoing. The description of the Zimbabwean road sector is made in terms of: contractors; plant and equipment; materials availability and influential factors.

a) Contractors

There are approximately 78 civil engineering contractors in the Zimbabwean road sector categorised from A to H. They consist of both local and foreign contractors and are members of the Construction Federation of Zimbabwe (CIFOZ). CIFOZ provides guidance on minimum conditions of work for their members which are legislated in Zimbabwe.

b) Plant and equipment

The condition of plant and equipment required for road construction is fairly good and is readily available within the country. It was not clear on the ratio of owned to hired equipment as this detail was not available. In addition, build-up of rates for equipment was not provided as it was considered private and confidential by contractors, since this was what provided them the edge against competitors. Therefore, it is not clear which method is used to calculate all-in-equipment hourly rates. However, the actual plant and equipment rates used by the Department of roads when evaluating tenders were provided.

c) Materials

About 40 percent of road construction materials were locally available and 60 percent were mainly from importations.

d) Cost factors

The Department of Roads indicated that the cost factors which had the greatest impact on unit rates were project scope, location of the site and its topography. On the other hand, the exchange rate had the least influence on unit rates, due to the fact that Zimbabwe transacts in the United States Dollars and this gives them a competitive advantage over their counterparts in the region.

The rates built up depended on the all-in-labour, material and equipment rates that were collected from the different road authorities. Table 7.3 shows the summary of projects used in the validation.

Table 7.3: Regional projects summary

S/No	Project Description	Country	Type of Intervention	Year
A	Upgrading of Lumbadzi-Dowa-Chezi (M7/M16) Road	Malawi	Asphalt	2008
B	Upgrading of Mzimba-Eswanzini-Mzarangwe Road Section	Malawi	Single seal	2009
C	Construction of Lilongwe Western Bypass Road	Malawi	Double seal	2012
D	Maintenance of Road/s D943 and D2500 from Gruisfontein to Bekend Valley in the Waterburg District of Limpopo Province	South Africa	Single / Double seal	2012
E	Roads Preventative Maintenance and Rehabilitation Project from R523 to Alldays in Senwabarwa Municipality in Capricorn District	South Africa	Single / Double seal	2013
F	Construction of Harare - Mutare - Noczim Access Road	Zimbabwe	Double seal	1989
G	Construction of Harare - Chitungwiza Road	Zimbabwe	Double seal	1989

Results

Table 7.4 shows a comparison of selected UCEM rates to those of Malawi projects.

Table 7.4: Comparison of selected UCEM rates to BoQ rates from Malawi

Pay code	Work description	Unit	Rates from the model (MK)	Malawi projects (Rates in Malawian Kwacha)		
				A	**B**	**C**
17.01	Clearing and grubbing	ha	750,857.14	219,700	75,750	588,369.00
22.18(a)	Brick work 115mm thick	m^2	5,005.71	1,560.00	1,818.00	-
23.01	Concrete kerbing	m	3,566.57	3,200.00	2,020.00	6,597.00
34.01(a)	Gravel selected layer compacted to 95% of MOD ASSHTO (200mm)	m^3	5,983.08	1,400.00	2,323.00	1,933.00
41.01(c)	Prime coat. MC-30 cut-back bitumen	litre	874.75	175.00	404.00	422.00
45.01(a)	Bituminous double seal 19 mm, 9.7mm aggregate	m^2	1,385.33	1,125.00	-	1,249.00

The results in Table 7.4 show that the model rates for Malawi were consistently higher than the actual rates from the BoQs. Apart from pay Items 23.01 on concrete kerbs and 45.01 (a) on double seal, the rates from the model are about twice the actual rates.

Table 7.5 presents results of selected UCEM rates to those of South African projects.

Table 7.5: Comparison of selected UCEM rates to BoQ rates from South Africa

Pay code	Work description	Unit	Rates from the model (Rands)	South Africa projects (Rate in Rands)	
				D	**E**
17.01	Clearing and grubbing	ha	19,714.29	5,000.00	8,000.00
23.01	Concrete kerbing	m	93.64	120.00	120.00
34.04 (k) (i)	Gravel base compacted to 98% of modified AASHTO density , using: Non-cemented material (150mm layer thickness)	m^3	157.09	50.00	50.00
35.03 (a) (i)	Chemical stabilizing agent: Common cements to SABS ENV 197-1, CEM IIB grade 32	tonne	2,300.00	-	1,750.00
41.01 (c)	Prime coat. MC-30 cut-back bitumen	litre	22.97	8.00	12.00
45.01 (a)	Bituminous double seal 19 mm, 9.7mm aggregate	m^2	36.37	50.00	50.00

From Table 7.5, it was noted that there was consistency in the rates between projects. Results show that the model rates are almost three times higher in some cases than the BoQ rates. Again pay items 23.01 on concrete kerbs and 45.01 (a) on double seal the rates from the model were lower than the BoQ rates. This could be attributed to either: varying specification for the concrete kerbs; the rate for double seal is a *rate only* so it can be priced higher as it does not have an effect on the tendered sum; or that there is an error in the calculation from first principles. Table 7.6 presents results of selected UCEM rates to those of Zimbabwe projects

Table 7.6: Comparison of selected UCEM rates to BoQ rates from Zimbabwe

Pay code	Work description	Unit	Rates from the model (ZDollars)	Zimbabwe projects (Rate in Zimbabwean dollars)	
				F	G
C.6	Chemical stabilizing agent: cement	tonne	1,396.00	696,009.61	696,009.61
R.3/R.4 C.8	Cast insitu concrete Grade 20	m^3	1,296.29	1,018,781.05	1,018,781.05
34.04(k) (i)	Gravel base compacted to 98% of modified AASHTO density, using: Non cemented material (150mm layer thickness)	m^3	95.35	292,540.21	292,540.21
R.16	Prime coat. MC-30 cut-back bitumen	litre	13.91	4,265.98	4,265.98

It was observed that Zimbabwe has modified the majority of the SATCC pay items. The method of measurement has been varied. The Zimbabwe Department of Roads provided Engineers' estimates for the two projects as opposed to actual contracts awarded, thus the identical rate for like descriptions. For Zimbabwe the rates vary. It was difficult to determine a trend. This could be attributed to change of the official currency from Zimbabwean Dollar to United States Dollars. Zimbabwe has gone through three re-denominations making it difficult to determine which to apply. The Department of Roads stated that there has been no funding for major projects since the economy underwent hyperinflation during 1997 - 2008. The BoQs provided were for the stable period before the hyperinflation. The department was trying to complete projects that were awarded during 1997 - 2008 as the currency of those projects was being converted to US dollars. The UCEM rates indicate what the rates in Zimbabwe should be.

7.5 Validation challenges

This section describes how the challenges encountered during validation were resolved.

7.5.1 Neural network

It was observed that the Project feasibility (pre-construction) factor should be more descriptive. From expert intuition and in consultation with the public roads agency RDA, the factor was changed to "Level of design" with four (4) input nodes: 1 = very good – detailed design available (prepared by a consultant); 2= good – preliminary design prepared by consultant; 3 = satisfactory – preliminary design prepared by client (RDA) to be reviewed by consultant; and 4 = Poor – sketch designs available.

Arising from the change of input nodes from five (5) to four (4) the data was checked and recalculated for neural network testing. The breakdown of the revised input data is shown in Figure 7.4.

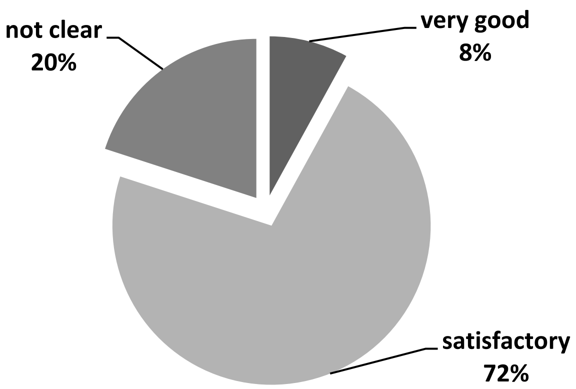


Figure 7.4: Breakdown of level of design data input

Information on 20 percent of the projects was not clear and could not be used in the training.

7.5.2 Local validation

The local validation using real system measurements did not provide conclusive results. It was difficult to justify any of the unit rates presented from real projects. Therefore, the model rates were subjected to further validation using expert intuition. Expert intuition involved examination of the model rates by someone other than the modeller, an "expert" with respect to the system, rather than with respect to the model.

The two experts identified, met the original criteria set under expert opinion as follows:

a) minimum academic qualification of first degree;
b) background in civil engineering or quantity surveying;
c) more than 10 years' experience;
d) able to build up road construction rates from first principles; and
e) worked on a project valued at NCC Grade 3 minimum limit of contract value under category R (roads).

One expert was a civil engineer from a consulting firm and the other was a quantity surveyor from the public roads regulatory agency therefore their expertise was considered sound. The two experts did not go through all the rates but applied the Pareto Principle which states that approximately 80 percent of the project cost is contained in 20 percent of the items. The experts were not concerned so much with the unit rate derived by the model but rather the first principles equations and assumptions made. The exercise led to the review of unit rate calculation for the following pay items:

a) all the 2300 series;
b) 26.03;
c) 35.01;
d) 35.02;
e) 42.02 (a); and
f) the entire 5000 series.

Series 5000 was a challenge because of the varied standards for road furniture such as road signs, marker posts, kilometre posts and guard rails. The final unit rates were based on drawings supplied by the consulting engineer. The drawings for road furniture used to derive unit rates for series 5000 pay items are attached as Appendix J.

7.5.3 Regional validation rates

The regional unit rates were not subjected to neural network prediction. This was because cost factors vary for each country. Therefore, the neural network was turned off during regional validation. Subjecting the regional unit rates to validation through theoretical results analysis, revealed that the derived results were consistently lower than the UCEM for Malawi and South Africa. This is consistent with literature which showed that the cost of fuel and cement were cheaper in South Africa as compared to Zambia. Therefore, the UCEM is functioning correctly as the derived unit rates obey the operational laws provided for the assumptions. However, unit rates from Zimbabwe suggest that further investigation into the detailed behaviour of the model was necessary.

7.6 Limitations of the model

During validation a number of limitations of the UCEM were observed.

7.6.1 Units of measurement

The UCEM utilises the metric system of measurement. The model does not have a feature for automatic conversion to imperial units of measurement. It is possible to incorporate this feature to improve functionality of the model in future.

7.6.2 Reference point of distance to project start point.

The model does not consider the varying unit rates of the same pay item depending on the length of the road project. For instance, for a road project of 285km, it was expected that the unit rate of laying drainage pipes at the starting point of the project at chainage 0.00km and mid-way of the road length, for example at chainage 100.00km, would vary because of establishment costs required at every 25km of the road project. The model does not accommodate different rates at start, mid or end point of the road. The current practice in Zambia is all encompassing considering the full length of the road and not sections. In addition, there was no research indicating the effect of distances on unit rates within the same project.

7.6.3 Project duration

The UCEM does not estimate durations for road projects. This is because duration calculation is a function of quantities of the project. The UCEM primarily derives unit rates only. But this function could be added to improve functionality of the UCEM.

7.6.4 Conceptual estimate

The UCEM was targeted at deriving definitive as opposed to conceptual estimates. However, this function could be incorporated to derive ball park figures when project data is minimal.

7.6.5 Variations

The model does not deal with variations as some of the activities fall under contract or project management. Treatment of variation varies. If variations were in terms of changes in quantity, the model would still only show the rate per unit. If variations were in terms of new items, then the unit rate could be derived if the pay item was in the SATCC specifications. However, the project management function could be considered for future functionality of the model.

7.6.6 Comparison with Consumer Price Index

Zambia lacks construction specific indices. The Consumer Price Index (CPI) is the most common index used in the Zambian road sector. Data stored by the UCEM in terms of labour, plant and material can be used to derive indices that could be used in the Zambian road sector.

7.6.7 Economies of scale

The model does not take into account economies of scale. No studies have been done in Zambia to determine at what point a road project would attain constant returns to scale.

7.6.8 Method statement

The model is not sensitive to the method statement of the project. For instance, the rate for pay Item 17.01 on clearing and grabbing does not change depending on whether the contractor uses manual or mechanical means.

7.7 Summary

Chapter Seven presented how the UCEM was developed and validated. The UCEM development incorporated neural network prediction and first principles estimating to establish unit rates for the Zambian road sector. Real system measurement validation with data from five projects from the Zambian road sector confirmed the need of a model as the rates presented were varied. Regional results demonstrated that the UCEM provided unit rates consistently higher than those pertaining in the three SADC countries. The developed UCEM would assist the road management system work smoothly and effectively through development of Engineers' estimates and formulation of annual work plans. The UCEM could assist contractors prepare competitive bids. Chapter Eight discusses the results of literature review, interview and questionnaire survey and validation findings.

Chapter Eight: Discussion of Results

8.1 Introduction

Chapter Seven presented the development and validation of the UCEM. The UCEM development incorporated neural network prediction and first principles estimating to establish unit rates for the Zambian road sector. Real system measurement validation with data from five projects from the Zambian road sector confirmed the need of a model as the rates presented were varied. Regional validation results demonstrated that the UCEM provided definitive rates consistently higher than those pertaining in Malawi, South Africa and Zimbabwe. This chapter discusses the results of the study. It considers literature review findings, expert opinions and questionnaire results in relation to local and regional validation outcomes and presents the concept of a hybrid neural network as a fifth generation cost estimating technique. The discussion in this chapter focuses on:

a) cost estimation elements;
b) construction cost indices in the Zambian road sector;
c) the potential of the UCEM; and
d) usage of hybrid neural networks in cost estimation.

Accurate cost predictability is perhaps one of the major requirements on any road construction project. A lack of understanding of the estimating process and cost control on road projects can result in under or over estimation. Estimating and bidding is not an exact science because of subjectivity from the estimator's experience, project scheduling, site supervision and productivity factors. In Zambia, because road project estimates are based on historical information, the unit rates can vary due to outdated data. In addition, the volatility of global prices such as those relating to oil based materials can adversely affect project cost estimates. Given the myriad of factors that affect cost estimation, it is important to understand them in order that some semblance of standardisation is obtained to explain the prevailing unit rates. Even though each project is unique, certain activities may be repetitive, similar or standard providing an opportunity for computer based cost estimation.

8.2 Cost estimation elements

Computerising the cost estimation process is one way of achieving accurate information. However, consideration has to be made about elements that go into cost estimation. These elements include cost estimate classification and associated accuracy, economic strata, first principles equations, appropriate software and model validation aspects.

8.2.1 Cost estimate classification

The key action to ensure better predictability in cost estimation is to recognize the degree of accuracy of the estimate being used (Canadian Construction Association, 2012). Literature reveals that a cost estimate classification system with three to five discrete categories is essential (AACE, 2013). This is important to avoid misinterpretation of the quality and value of the information available to prepare cost estimates. The various methods employed during the estimating process and the accuracy levels expected have to be incorporated in a cost classification guideline. Interview findings revealed that as a country, there were no documented cost estimate classification guidelines. From the questionnaire survey, respondents indicated that through their experience, they had established informal methods of estimating costs which included use of historical rates as well as building up rates from first principles. In the Zambian road sector, existing undocumented protocols that are broadly understood indicate four types of estimates namely: budget; preliminary; engineers estimate after detailed design; and tendered amount. It was therefore critical to recommend a cost estimate classification system to benefit from the proposed UCEM. The recommended cost estimate classification can also be used to provide a basis for projects that are shelved at any stage. The recommended classification system for the UCEM is presented in Table 8.1

Table 8.1: Recommended cost estimation classification for the Zambian road sector

	Class4	Class 3	Class2	Class1
Estimate Type	Feasibility	Preliminary	Elemental	Unit price
Confidence	Very low	Low	Medium	High
Expected Accuracy	±30%	±20%	±15%	±10%
Input to	Feasibility report	Project budget	Cost management	Construction budget and cost control
Available information	Sketchy	Limited	Detailed	Complete
Output type	Ball park (global)	Rate/km	Rate/element (trade)	Rate/ unit (activity)
End usage	Concept	Budget	Engineer's estimate (management report)	Authorisation/ check tender/ Cost

From Table 8.1, estimates derived from the UCEM are targeted to fall under Class 1. Reviewed literature indicated that a conceptual estimate had an acceptable accuracy of ±20 percent compared to a definitive estimate with an expected accuracy of ±10 percent. The recommended cost estimation classification has gone further and increased the expected accuracy for Class 4 estimates to ±30 percent. This is because the Zambian road sector does not have construction cost indices which would present historic changes in civil engineering costs. Therefore, conceptual estimates are not prepared using accurate available scientific construction specific data. To complete the classification system, the documents required for each estimate class should be stated in detail. This is beyond the study but could be considered as future research.

The rational of categorising the classes from four (4), representing conceptual estimates to one (1), for definitive estimates considered contractor grading adopted by the National Council for Construction (NCC). This was done to achieve some semblance of standardisation in the construction sector. At NCC, small scale contractors who are in the majority are in higher numerical categories such as grades 5 and 6 compared to large scale contractors who are fewer in number and are placed in lower numerical grades such as 1 and 2.

The recommended cost estimate classification should prompt the Surveyors Institute of Zambia, Quantity Surveying Chapter to establish guidelines. These guidelines could enhance the confidence of the public in the quantity surveying profession. The quantity surveying body could use the cost estimate classification guidelines to monitor the profession and its impact on the construction industry. For instance, if an estimator or quantity surveyor continues providing estimates that are beyond the stated accuracy for say five projects, then the quantity surveying chapter could recommend further training for the estimator. One of the key indicators for the profession would be the number of project estimates within classified accuracy. This could also apply to the Association of Consulting Engineers (ACEZ) whose members provide the engineer's estimate on behalf of the Road Development Agency. The Road Development Agency could include the engineer's estimate assessment in their vendor rating system. If a consulting engineer provides inaccurate estimates for say five projects in any given year, their rating could be lowered. Once the consultants know that someone would check their engineer's estimate they would pay attention to the estimate provided. Once a consulting engineer provides an engineer's estimate, there is no analysis as the client does not have the capacity to do so. The UCEM would therefore assist in standardising engineer's estimate requirements through cost estimate classification.

8.2.2 Establishment of cost factors

Another aspect the UCEM would standardise are the factors incorporated in determining an estimate. The problem statement of the study indicated that stakeholders had requested guidance on what constituted construction unit rates in Zambia as there was no basis of estimates used in the industry. The construction industry, public procurement and public roads regulatory bodies called for an informed position on prevailing market rates in the Zambian construction industry (Times of Zambia, 2010; Road Development Agency, 2012; Zambia Public Procurement Authority, 2014). Blocher et al. (2008) stated that selecting relevant and appropriate cost drivers was the most important step in cost estimation as it affected a model's accuracy. Therefore, selecting and assessing factors that account for cost variations across road construction projects in Zambia was critical to the study.

Literature revealed that factors affecting construction unit costs vary, depending on a country's political, economic, social and technological inclinations. Since analysis of cost factors requires an appreciation of a country's practices, the identified drivers then provide an indication of a country's construction economic strata. The 45 cost factors identified from literature were reduced to 31 using Pareto analysis. These were further reduced to 25 following expert opinions from practitioners. To obtain conclusive results on factors influencing road construction unit rates, the 25 factors hereafter referred to as variables, were subjected to a questionnaire survey. Using Statistical Package for Social Sciences (SPSS) version 20 and in particular, factor analysis, the variables were further reduced to 8. Literature indicated that the number of influencing factors used in similar studies in neural network averaged 9.9 factors, therefore eight was deemed sufficiently close. Incorporating validation findings, the eight variables were renamed as: contractor capacity; project location; period of honouring payments; level of design; cost escalation; materials availability; country corruption profile; and political environment. The cost factors provide an insight into the Zambian road sector economic strata. Literature revealed that periodic review of cost factors is essential because of countries' constant political, economic, social and technological transformations. In 2009, influencing factors in Zambia included advance payment, type of project consultant and competition (RDA, 2009). However, these were found to have minimal influence in this study. Arising from this, an option to turn off factors was incorporated in the UCEM.

Ideally, the model should have incorporated all the 25 factors derived from literature review and subjected to expert opinion. An option to turn off each factor as political, economic, social and technological elements change should have been provided. At the time of cost factor review, the required factors would be turned on ensuring that less than 10 neural network factors were operating at any one time. With all the factors readily in the model, any change in the economic strata would entail a click of a button. This could be an area of further study as it was not accomplished due to programming and financial limitations. Furthermore, the developer of neural network software, NeuroShell 2, indicates that a good rule of thumb is the number of training patterns should equal 10 times the number of inputs. This would have entailed that the number of projects required for training of 31 factors should have been more than 310. The researcher was doubtful if that many projects would have been availed by the institution responsible for public road sector.

Cost factors are qualitative and are therefore difficult to quantify. This research established the breakdown of the economic strata through the use of neural networks.

The economic strata defined as the difference between the prevailing market rates and the base rate was determined. The resulting ratio of the factors, namely, political environment, contractor capacity, period of honouring payments, level of design and cost escalation was 4:2:1:1:1 respectively. Therefore, political environment was 44 percent of the unit rate followed by contractor capacity at 22 percent and period of honouring payment, level of design and cost escalation each at 11 percent. The uncategorised factors namely: project location; material availability; and country corruption profile had minimal impact on unit cost. This is attributed to the constant input nodes of the projects used to train the neural network. For instance, the CPI was the same for all projects because the CPI changes annually and Zambia has been in the same range for the past 5 years. The variation in distance of the sample projects was not high and material availability was normal without severe shortages.

Knowledge of cost factors affecting the road sector can be beneficial to all stakeholders. At face value, cost factors would give a contractor an indication of whether certain projects are worth undertaking or not. Contractors would know which factors to consider when determining prices in their tenders. They would be better placed to mitigate risks emanating from a particular cost factor such as project location. This would make contractor pricing more competitive.

Understanding the cost factors relevant to public infrastructure would prompt government to introduce policies that would reduce the impact of that factor. For instance, one of the established factors was project location. If government realises that project location has an impact on road construction costs, they could introduce road sector regulations under the existing decentralisation policy that could ensure that only contractors in the proposed project locality could tender for the works. The Zambian road sector has been centralised in its operations. Findings indicated that about 92 percent of the contractors in the Road category mobilised from the capital city, Lusaka. Bidders lose more money when the distance between the project location and a firm's operational office is greater. Literature revealed that within SADC, Zambia was one of the countries with very poor roads while South Africa had very good trunk roads. This could be attributed to the procurement regulations pertaining in South Africa. The regulations authorise South African contractors to bid for projects in the region of the contractors registered office. The requirement to bid regionally could initially be included under preferential procurement where discounts on the tendered amount are given to contractors in a particular region. The Road Development Agency (RDA) has made efforts to decentralise its operations. It has set up regional offices in all provinces in the country. However, its implementation of fiscal decentralisation is lagging behind. Fiscal decentralisation enhanced knowledge of local needs and preferences, specific to a locality, thereby, providing effective targeting of public services (Zambian Economist, 2014). Fiscal decentralisation in the road sector can be achieved by establishing procuring units in the regional offices to ensure efficient, effective and uniform procurement of road works. Regarding the established cost factor on contractor capacity, government could establish a policy on mandatory joint venture bidding. This is where rules are relaxed for international contractors to come into the country but they are required to partner with local contractors to bid for any road projects. Therefore, cost factor analysis can be used to evaluate the desirability of a given policy.

Quantifying cost factors provides a basis of comparison between projects. Consultants analysing unit rates on varying projects can remove the cost for the factors and use the base rate to compare with their rates built from first principles. In the absence of tender price indices, consulting engineers can come to a consensus on the principal cost factors and apply them to predict the bidding trend in the road sector. Knowledge of cost factors is important as it provides an understanding of the construction sector. During the course of the study, the South Africa Construction Industry Development Board (CIDB) requested a study of the drivers of construction costs (CIDB, 2015).

Finally understanding of cost factors can assist in the development of construction indices. In the formation of construction cost indices (CCI), identification of the base year is paramount. A base year is a year in which there are no anomalies in price variations and in the level of production. The base year should be as recent as possible but comparable with other data indices at national level. Cost factors can be used to determine the base year. The selection can be based on the year when cost factor input nodes were favourable or neutral. The year when conditions are as shown in the last column of Table 8.2 are met could be the base year.

Table 8.2: Base year selection input node for construction cost indices

S/No.	Cost factor	Factor input node	Base year selection input node
1	Contractor capacity	1 = Grade 1; 2 = Grade 2; 3 = Grade 3; 4 = Grade 4; 5 = Grade 5; 6 = Grade 6; 7 = ungraded	1 (best criteria)
2	Project Location	1 = very near (<100km); 2 = near (101-300km); 3 = average (301-500km); 4 = far (501-700km); 5 = very far (701-900km); 6 = extremely far >901km	3 (average criteria)
3	Period of honouring payments	1= up to 28 days; 2= up to 35 days; 3 = up to 42 days; 4= up to 49 days; 5= up to 56 days; 6= up to 63 days; 7= up to 70 days; 8= up to 77 days; and 9= up to 84 days	1 (best criteria)
4	Level of design	1= very good; 2=good; 3= satisfactory; 4= poor; 5=unacceptable	1 (best criteria)
5	Cost escalation	1 = 0%; 2 = 5%; 3 = 10%; 4 = 15%; 5 = 20%; 6 = 25%; 7 = 30%; 8 = above 35%	1 (best criteria)
6	Materials availability	1 = available locally; 2 = available imported; 3 = shortages; 4= severe shortages	1 (best criteria)
7	Country corruption profile	1=very clean (100-80); 2= clean (79-60); 3= moderate (59-40); 4= corrupt (39-20); 5= highly corrupt (19-0)	1 (best criteria)
8	Political environment	Political interference 1=none; 2= low; 3= moderate; 4= high; 5= very high	1 (best criteria)

Initially, the base year is usually the first year. The cost factor input node of the first year could be captured and recorded to form the basis of future revisions. By using information from cost factors, the selection of the base year would be made simpler as well as objective.

It is hoped that improvement of the Zambian road sector for effective delivery of roadworks can be achieved with a thorough understanding of cost factors that affect unit rates integrating first principles estimating. Understanding cost factors provides a formal and documented process for adjusting unit costs for project characteristics and market conditions.

8.2.3 First Principles estimating

The Oxford Advanced Learner's Dictionary (2014) defines first principles as the fundamental concepts or assumptions on which a theory, system, or method is based. A famous quote by Harrington Emerson (1911) states *"As to methods there may be a million and then some, but principles are few. The man who grasps principles can* *successfully select his own methods. The man who tries methods, ignoring principles, is sure to have trouble."*

The concept of first principles has been applied to construction cost estimating. Molenaar et al. (2011) reported that estimating from first principles was the preferred method for contractors bidding for heavy highway type of work. Results from the questionnaire survey indicated that 27 percent of respondents in Zambia build up rates from first principles compared to 55 percent who use historical rates. This could be due to lack of documented production rates and construction specific indices required for first principles estimates in the Zambian road sector. Estimating from first principles requires careful review of work crews and equipment completing tasks at assumed rates of productivity. Molenaar et al. (2011) further stated that although more time and skill were required in first principles estimating compared to historical based estimating, once the appropriate labour and equipment production data sources and material price database are created, the process is routine and manageable. Therefore, it was advantageous to use the same approach in preparing engineer's estimates resulting from the model. Since the method of measurement is standard in the Zambian road sector, the pay items were calculated from first principles by obtaining the total hourly rates for labour, equipment and materials divided by the specified output to come up with unit rates.

From literature, it was not clear which software was commonly used among contractors and practitioners in the Zambian road sector as no published research could be cited. The questionnaire survey findings indicated that only 4 percent of the respondents used software. Experts revealed that Microsoft excel was used for first principles estimating. The background engine for the UCEM utilised an excel format to calculate unit rates as shown in Table 8.3.

Table 8.3: Excel format for first principles estimating in the UCEM model

Pay item A	Description B	Unit C	Qty D	Rate E	Total F
	1. Labour (DxE)				
	2. Equipment(DxE)				
	3. Material (DxE)				
	4. Total (1+2+3)/output				

Using excel the total hourly rate for labour, equipment and material were added and then divided by the specified output to come up with the unit rate.

The Canadian Construction Association (2012) recommends the use of appropriate economic models in the estimating process to ensure improved cost predictability. Because the process of first principles estimating was routine and manageable (Molenaar et al., 2011), it was prudent to computerise the process to reduce the estimating period. Even though the basic background engine for the model uses excel, it was necessary to incorporate current technologies to make the UCEM practical. It was important that the model was user friendly, practical and functional.

The model is user friendly in that it has a streamlined layout and appearance which does not include unnecessary images and flash animations. It is practical in that the model is web based and uses popular web technologies and frameworks such JQuery and Bootstrap. It can be accessed from any part of the world even on tablet or mobile phone as long as there is internet connectivity. The model is optimized to display correctly on each of these devices. The UCEM model is functional in that it has incorporated both quantitative and qualitative factors to produce a unit cost rate. To improve on performance and loading times, the model uses AJAX which allows certain parts of a website to update without refreshing the entire page. This behaviour is evident when expanding and collapsing items on Bill of Quantities.

8.2.4 Series 1000 - General

Series 1000 deals with preliminary and general (P&G) items specifying project mobilisation. The desk study revealed that more than half the pay items under series 1000 are lump sum. Even with a good database, items that are bid lump sum are difficult to price as they vary from project to project. Using lump sum items typically transfers risk to a contractor. Literature revealed that lump sum items are typically bid at higher costs than component costs due to the transfer of risk from the owner to the contractor.

Mobilisation is a contract pay item used to cover a contractor's pre-construction expenses and the costs of preparatory work and operations. Since there is no clear list defining this work effort, and contractors have the ability to adjust their bids as needed to cover these expenses, there are no true rules as to what percentage should be used per project. The Cost Estimating Manual for Washington State Department of Transportation (WSDOT) Projects recommends 10 percent for P&G items but allows for adjustments as shown in Table 8.4.

Table 8.4: Recommended percentage calculation for P&G items

S/No.	Contract Amount in US$	Percentage for P&G items
1	less than $100,000	8% - 12%
2	$100,000 - $250,000	6 % - 10 %
3	$250,000 - $500,000	6 % - 9%
4	$500,000 - $1,000,000	5 % - 9 %
5	$1,000,000 - $2,000,000	6 % - 9 %
6	$2,000,000 - $5,000,000	7 % - 9 %
7	$5,000,000 - $10,000,000	8 % - 10 %
8	$10,000,000 - $20,000,000	7 % - 11 %
9	Over $20,000,000	7 % - 10 %

Table 8.4 indicates that mobilisation costs of between 8 to 12 percent for projects less than US$ 100,000.00 is acceptable. But to accurately calculate the preliminary and general items percentage that should be used for each individual project, consideration should also be given to:

a) the location of the project;
b) the complexity of the project;
c) the need for specialized equipment;
d) the type of work being performed;
e) rural vs. urban projects with multiple work sites;
f) excessive preparatory removal items;
g) large quantities of excavation; and

h) spanning of constructions seasons when it would become necessary for the contractor to shut down and clear the work site between these seasons.

8.2.5 Validation

Literature revealed three (3) validation techniques namely: expert intuition; real system measurements; and theoretical results analysis. In this study, real system measurements was used in both local and regional validation. This was followed by expert intuition in local and theoretical results analysis in regional validation.

The UCEM, which was validated locally using real system measurements from five projects from the Zambian road sector, did not provide conclusive results. It was difficult to compare the rates from the UCEM to those in the BoQ's. The varying rates could be attributed to contractors' costing strategies such as *front loading* where rates for activities that are scheduled early in the work programme are higher than those that come at the end. Another strategy is *quantity sensitivity*. Contractors tend to lower the rate of items with high quantities as compared to those with low quantities so that the tendered sum is competitive. The third strategy is *work activity probability*. In this case the contractor considers the chance of a work item being undertaken. The large disparities of unit rates confirm desk study findings in the statement of the problem. Because the unit rates from the model were not conclusively validated, they were subjected to expert intuition. Expert intuition involved examination of the model rates by someone other than the modeller, an "expert" with respect to the system, rather than with respect to the model (Hillston, 2003). Two experts were selected and their intuition relied on: experience in building up of rates; and knowledge of construction methods, new technologies, building regulations, market trends, labour, equipment and material costs. The experts did not go through all the rates but applied the Pareto Principle which states that approximately 80 percent of the project cost is contained in 20 percent of the items. Therefore, unit rates under series 3000 and 4000 were examined. The experts were not concerned so much with the unit rate derived by the model but rather the first principles equations and assumptions made.

SADC countries utilise SATCC specifications and therefore provided an opportunity to compare and validate like pay items. Landlocked SADC countries like Malawi and Zimbabwe were selected as they were likely to have similar road network requirements as Zambia. South Africa being one of the SADC countries with very good trunk roads was also selected as a benchmark for SADC, and in particular Zambia.

Regional validation from real system measurements revealed that unit rates in the Zambian road sector were higher than South Africa and Malawi. This was consistent with literature which showed that the cost of fuel and cement were higher in Zambia compared to South Africa and Malawi. Therefore, validation through theoretical results analysis confirmed that the model was functioning correctly as the derived unit rates obeyed the operational laws provided for the assumptions. However, unit rates from Zimbabwe suggested that further investigation into the detailed behaviour of the model was necessary.

8.3 Construction cost indices in the Zambian road sector

Desk study findings revealed that Zambia lacks construction specific indices. The use of construction cost indices (CCI) is virtually non-existent in Zambia. The Consumer Price Index (CPI) is the most common index used in the Zambian road sector as a basis for cost estimation. The CPI, if not applied appropriately could result in inaccurate road infrastructure cost estimates. CCI is an indicator of the average cost movement over time of a fixed basket of representative goods and services related to the construction industry (Swarup, 2008). CCI are generally calculated quarterly to provide planners with a tool for estimating the cost of future construction projects.

Results from the questionnaire survey indicated that the majority 55 percent of respondents in Zambia use historical rates in preparing their tenders. CCI would therefore be suitable because the multipliers would be used to convert costs from past projects to current estimated cost of performing the same project.CCI are the easiest and fastest way to update historical project costs to reflect costs in the current market.

One would rationalise that if CCI were available in the Zambian road sector, cost escalation would probably not have been a factor because CCI provide an insight into the trend of construction costs in the market. Availability of CCI would be beneficial to effective cost management of construction projects. Contractors would be able to incorporate predicted price variations in their estimates and prepare bids with higher accuracy.

From contractors' perspective, CCI clauses shift business risk to the employer. This could result in contractors' willingness to submit lower bids but this would be dependent on project duration. The use of CCIs is usually considered for long term projects. In the Zambian road sector, the price adjustment clause which employs the CPI is usually applicable for projects with a duration of eighteen (18) months or more. Therefore, CCI forecasting could be used to reduce construction costs by better-timed project execution. Furthermore, CCI assist in tracking the cost of construction in a particular location. There are broadly understood guidelines regarding the cost of construction in different provinces in Zambia, but these are not consistently well documented. The UCEM has attempted to incorporate regionally sensitive rates, but once again this employed the CPI, as there were no documented location indices.

SADC has harmonised the consumer price index (CPI), a measure of price inflation. The first SADC Harmonised Consumer Price Indices (HCPI) were released in January 2011. The main objective of the HCPI is to have one index for SADC and COMESA, respectively, as well as to facilitate comparison of indices within these regions through the adoption of one standard of classification and acceptable methods of compilation. Mpofu and Munalula (2012) reported that the SADC HCPI has the potential for extension to a continental index. Based on this premise, SADC may consider harmonisation of CCI. Harmonisation of CCI would require SADC member states to avail such statistics.

Data stored by the UCEM in terms of labour, plant and material can be used to derive CCI that could be used in the Zambian road sector. The study recommends the development of CCI as a consequence or derivative of the UCEM.

8.4 Potential of the UCEM

The UCEM is a computerised cost estimation model to provide an engineer's estimate for various road projects, be it periodic maintenance, rehabilitation, construction, upgrading, reconstruction for both paved and unpaved roads in Zambia. Though some systems have been developed in the past primarily on an ad-hoc basis and for specific types of roadwork, these systems do not appear to be in regular use (RDA, 2009).

Development of the UCEM was one of the ways to rationalise Zambia's perceived high road infrastructure costs. Estimating in the Zambian road sector is carried out by a wide range of personnel who subscribe to protocols that are broadly understood, but are not consistently well documented. The UCEM provides a standardized procedure of pricing road construction activities in Zambia, to ensure uniformity in public and private procurement practice. The potential of the UCEM are varied. Among them are regulatory and pricing requirements, labour and management perspectives, and investment decisions about the optimal mix of inputs to employ in the production process.

8.4.1 Regulatory and pricing requirements

The traditional method of procurement is the most common in the Zambian road sector. This is where the designer is responsible for design and the contractor for execution. With the UCEM providing accurate engineer's estimates, the Zambian road sector can migrate from least cost selection (LCS) to best value selection (BVS) in procurement of works. In best value selection the engineers estimate is known and contractors bidding within ±25 percent are evaluated. The current evaluation process considers a preliminary, financial and post qualifying evaluation. The BVS recommends consideration of cost, preliminary then project specific indicators (PSI). The first step is to check for correctness of the bill of quantities (BoQ) and verify that the total amount is within the engineer's estimate range. Then the basic requirements can be assessed using the 'yes/no' criteria as is the case under preliminary examination. For instance, availability of contractor registration certificate in the right category and grade, power of attorney, bid security, site visit certificate and any other specified requirements. This is then followed by a PSI evaluation or detailed examination. PSI which would be scored out of 100 would include contractor general and specific experience, the company's financial status, subcontracting methodology, method statement, safety record, HIV awareness strategy, key personnel and equipment requirements. Comparison of the existing and proposed BVS process is shown in Figure 8.1.

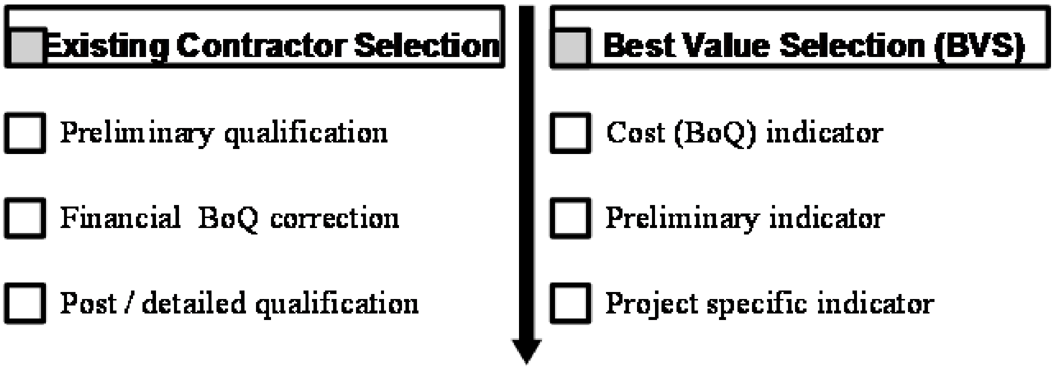


Figure 8.1: Comparison of existing and best value contractor selection process

The corrected total bid amount divided by the PSI score would give the VfM score. The contractor with the lowest VfM score would be the best value evaluated bidder. With the engineer's estimate known, contractors can decide whether they would bid for the work or not at the onset.

8.4.2 Pricing mechanisms

The UCEM provides a rate analysis system that can be used as a basis to compare against. In both the local and regional validation unit rates were compared.

i. Price list

The public procurement regulatory body, ZPPA, has on its website prices for common user items under procurement of goods. These prices are categorised geographically. The UCEM can provide region specific prices for common user items under procurement of roadworks. For instance, prices for earthwork (excavation and embankment) per m^3, concrete pavement per m^3, hot mix asphalt per m^2, double surface dressing per m^2, structural steel per tonne, structural concrete per m^3, reinforcing steel per kg, drainage per m, guardrail per m, maintenance of traffic per km and pavement marking per km can equally be made available to the public. This information would help in standardising the estimating process.

ii. Equipment

Literature revealed that there were four common methods of calculating ownership and operating costs for equipment. The research revealed that there were no documented methods or requirements set by the client in the Zambian road sector. The UCEM adopted the caterpillar method which provided an average rate per hour when compared to the other methods. The Road Development Agency can benchmark this as a pricing mechanism for equipment in the industry. This rate can be used to check the plant and equipment day-work rates included in the contractors BoQ. The current practice requires the contractor to insert the specified equipment hourly rate where Road Development Agency has indicated the total time required under day-works. With the UCEM calculating the hourly rates, the Road Development Agency can use them to calculate the dayworks and include them as fixed sums in the BoQ. The same can be done for labour.

iii. Labour

The UCEM calculates labour all in rates for all categories from first principles. Findings revealed that:

i. the UCEM rate was approximately 300 percent of the gazetted basic wage; and

ii. current rates show a lower figure for a general unskilled worker and a higher one for a foreman when compared to the UCEM.

The information provides the various stakeholders with an insight into the road sector labour market. The difference in unskilled and skilled rates to the UCEM figures are attributed to non-provision of some of the stated conditions of service to general workers such as medical insurance. In addition, most of the general workers are considered casual. This is further exacerbated by ignorance of the conditions of service by the general workers themselves. In contrast, foremen were provided with all the conditions of service and incentives. Contractors placed more attention on foremen who were considered as permanent staff. The gazetted basic wage rates are revised annually. Therefore the skewed pricing can be corrected through annual publication of labour rates derived from the UCEM.

iv. Economic strata

UCEM provided a framework within which to assess the economic strata and also shed light on cost factors that account for cost variations across projects. A detailed discussion on benefits of quantifying and understanding cost factors was made in Section 8.2.2 above. Cost factors give an indication of the risks involved in a particular industry. Contractors can estimate risk that is predictable. They can mitigate increasing costs because they give a best price in a predictable environment. The effects of the known cost drivers can be included in the contract clauses and estimated.

v. Other considerations

Literature indicates that competition has an effect on cost. For instance, limited resources in terms of skilled labour, equipment or material would result in an increase in project costs. Similarly, when the number of contractors increases on the market, it is expected that overall bid cost will be lowered. Contractors' bids are an indicator of the prevailing competitive market conditions. However, this cannot be said of the Zambian road sector. Findings show an increase in unit rates of various items. The Zambian road sector has not been able to establish why an increase in the number of players has had no meaningful impact in reducing construction rates. Failure to recognize how a competitive market may affect bid prices underpins the difficulty to ascertain the true cost of projects and thereby unable to guarantee VfM.

8.4.3 Standardisation

The building up of all-in rates for equipment and labour from first principles fosters standardisation.

i. Method of measurement

The unit rate or pay item activities are based on the standard Bills of Quantities template used in the Zambian road sector. The method of measurement is based on the Southern Africa Transport and Communications Commission (SATCC) Draft Standard Specifications for Road and Bridge Works – September 1998 (Re-printed July 2001). These standards have been in draft form since 1998. The Zambian road sector has been using these specifications and as such the SATCC descriptions were used as a basis for the UCEM. But desk review revealed the use of "B pay items" especially under series 1000, 2000 and 5000. The B pay items are revised or modified SATCC descriptions to suit existing practise. For instance the road signs under series 5400 are measured in square metres. The B item describes the complete road sign with board and post and the measurement indicated as number. However, it was observed that the revisions were not consistent. Moreover, the fact that the specifications have been in use for the past 17 years suggests time for revision due to technological advancement. The study therefore calls for the revision of the SATCC specification to ensure that the method of measurement is responsive to the Zambian road sector. Subsequently the revised pay items can be incorporated into the UCEM.

In addition, the study observed the need to categorise the work activities according to: upgrading to bituminous standards; new construction; routine and periodic maintenance; and rehabilitation of paved and unpaved roads. Besides, the daywork items are currently isolated and require to be incorporated as pay items. This has been achieved in the UCEM. The UCEM provides for creation of new series. For the daywork items, a new series 8000 was created. The labour daywork rates are categorised under 8100, material as 8200 and plant and equipment as 8300. Twenty (20) B pay items have been incorporated in the UCEM to illustrate that this can be done. Incorporation of the common and most frequently used pay item in the UCEM will make it a more valuable tool in BoQ and engineer's estimate preparation Standardising the method of measurement will provide uniformity and consistency in the Zambian road sector.

ii. Equipment

The Zambian road sector has seen the proliferation of all kinds of heavy construction equipment on the market. Heavy construction equipment is critical for any road construction project as it is used extensively to reduce labour cost and time. The wide spectrum of heavy construction equipment should be monitored to ensure efficiency and availability of spare parts for preventive maintenance. Adoption of the caterpillar method to calculate ownership and operating costs for equipment sets standards for efficient operation. It benchmarks the expected output of the equipment.

iii. Labour

The UCEM provides a standardised method of calculating the all-in labour rate. Once agreed with stakeholders, the UCEM labour method (ULM) can be adopted for the road sector. In addition, the influx of Chinese contractors in the Zambian road sector has led to new classification of labour categories. The Chinese contractors have introduced the expatriate foreman and expatriate equipment operator categories. These positions are not gazetted and the rates used cannot be verified but have somehow been accepted in the industry. The UCEM could not incorporate these categories as there was no basis for building up the all-in-labour rate. Therefore, if stakeholders require a new category established, the UCEM would provide pointers on the standard items required for consideration.

iv. Ancillary roadworks

It was difficult to derive base rates for certain items such as marker and kilometre posts due to inconsistent specifications. Figure 8.2 illustrates varied road specifications for ancillary works.

Kilometre post on Lusaka-Kafue Road | Marker post on Kafue-Mazabuka Road | Marker post on Lusaka-Kafue Road

Figure 8.2: Varying kilometre and marker posts

Findings from validation revealed that the unit rates for items under series 5000 could not be compared due to non-standardisation. Currently the BoQ rates vary depending on size and specification of the road furniture. For the UCEM, standard drawings for road furniture were produced to derive unit rates for series 5000. Standardising items like road signs, marker posts, kilometre posts and guard rails would ensure that a consistent rate is developed. It is for that reason that the UCEM calls for the standardisation of road furniture in the Zambian road sector.

v. Regional requirements

Input and output data for the UCEM could be incorporated in the Regional Statistical Development Programme for coordination and validation of road sector unit rates in the SADC region to facilitate comparisons between member states. Road sector unit rates should provide a solid base for strengthening informed policy-based decision making for the region’s economic cooperation and integration.

8.4.4 Efficiency of the Zambian road sector

Reviewed literature revealed that the national roads system in Zambia was experiencing increased activity following the rise in public spending in the sector. But there was concern as to whether the sector was operating efficiently. Determining the efficiency of the road sector can be challenging but with official standard productivity rates, this can be done. Estimating from first principles entails that outputs of the labour-material and equipment mixes should be known. Reviewed literature indicated that there were no official current publications of productivity data for the Zambian road sector. Production rates for plant and construction workers are virtually non-existent. In contrast, other economies have readily available productivity data which is published annually in some cases. Industry accepted data resources such as RS Means Heavy Construction Cost Data, Spon's Civil Engineering and Highway Works Price Book 2014 were used with caution for adoption to the Zambian road sector. Improvement of labour productivity should be a major and continual concern of those who are responsible for cost control of road infrastructure. Lack of official labour production rates make it hard for planning engineers to come up with contract duration, work schedule, costs and load estimates and budget and cost control systems.

Analysis of the productivity output rates used in the UCEM showed that they were half of those used in the road sector in India. Therefore, the UCEM provides an insight as to the efficiency of the sector. There was potential to improve efficiency in the Zambian road sector by increasing the productivity output rates.

8.4.5 Other uses

Literature showed that in the Zambian road sector, both consultants and contractors have developed their own databases of unit rates from past contracts. A database where variables can be stored and updated when required was an essential component of the UCEM. Therefore, a UCEM variables form has been generated and is presented as Appendix K. The developed UCEM database can serve as a register of projects in the road sector. The UCEM can store information on the nature, value and distribution of projects. Information regarding the number of on-going projects in any province or countrywide at any given time would be readily available. The UCEM database can be used in the establishment of an official road sector library whose information could be accessed online. A small fee could be charged for maintenance of the database.

8.5 Usage of hybrid neural networks in cost estimation

Substantive research has been undertaken in the application of neural networks as a prediction tool in various fields in the construction industry. Literature showed that potential application of neural networks includes but is not limited to:

a) preliminary cost estimation of road projects (Al-Tabtabai, et al.,1999) (Ayed, 1997);
b) cost estimation of timber bridges (Creese and Li, 1995);
c) cost estimating for structural steel framing (Moselhi and Siqueira, 1998);
d) cost estimation of carbon steel pipes (de la Garza and Rouhana, 1995);
e) forecasting low cost housing demand (Bakhary et al., 2004);
f) determining escalation to a construction estimate (Butts, 2007);
g) estimating the cost of change orders (Moselhi, 2003);
h) preliminary estimate of time and cost in urban road construction (Peško et al., 2013);
i) construction of labour production rates modelling (Muqeem et al., 2011); and
j) assessing productivity of earthmoving machinery (Krzysztof & Hola, 2007).

Literature points to the use of parametric estimating during the early stages of project development. Cost prediction using artificial intelligence presents the future of cost estimation. Reviewed literature indicated that neural networks have been used primarily for conceptual cost estimation in highway projects. Neural networks produced better cost predictions than conventional costing methods and were advantageous over parametric approaches. Because of neural networks' wide use in conceptual estimates, the same principle was applied to economic strata analysis. Literature suggests that back propagation is the training algorithm most commonly used for the development of civil engineering cost estimation. However, the study employed the Kohonen architecture because it has the ability to learn without being shown in advance how to categorize data fed into it. The Kohonen architecture is one of the least used in neural network architecture and literature on its use is limited. In addition, there are few experts in the field able to interpret neural network results. Therefore, neural network results would have to be subjected to experts to confirm interpretation of results.

Broadly stated, there are four generations of cost estimation. The concept of hybrid neural networks is being proposed as the fifth generation in cost estimation. The five generations of cost estimation are shown in Figure 8.3.

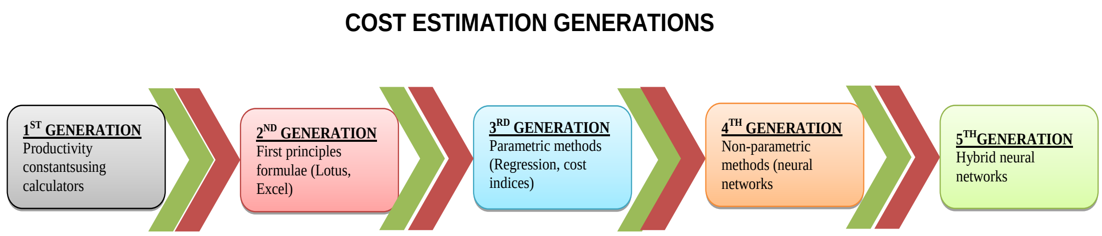


Figure 8.3: Generations of cost estimation

The first generation in cost estimation goes back to the 1940s-1950s when Spence Geddes recorded the use of productivity constants for cost estimation of construction works. The estimation process was manual or with the use of basic calculators. The introduction of computers unleashed various software that incorporated first principles formulae as the second generation in cost estimation. The use of parametric methods such as linear and non-linear regression or the use of cost indices in cost estimation signalled the third generation. The fourth generation considers the use of non-parametric methods or techniques that mimic the brain. The fifth generation is the notion of hybrid neural networks. Suffice to note, the generations overlap and some estimators are still using first generation methods to estimate construction costs.

The theoretical basis of hybrid neural networks is to utilise actual current or in other words *'live'* data to train the neural network. It is a well-known fact that an estimator's experience is a major factor in cost estimation accuracy. A single decision by estimators can make or break a project. The guide to cost predictability in construction details the qualification and experience required of estimators and cost consultants. For an estimator to produce an accurate cost estimate, they must be well informed about all aspects of the construction industry. A hybrid neural network (HNN) should mimic a successful estimator. The HNN should be able to process different aspects of an estimate. Figure 8.4 illustrates the various neural networks that would be required to form an HNN.

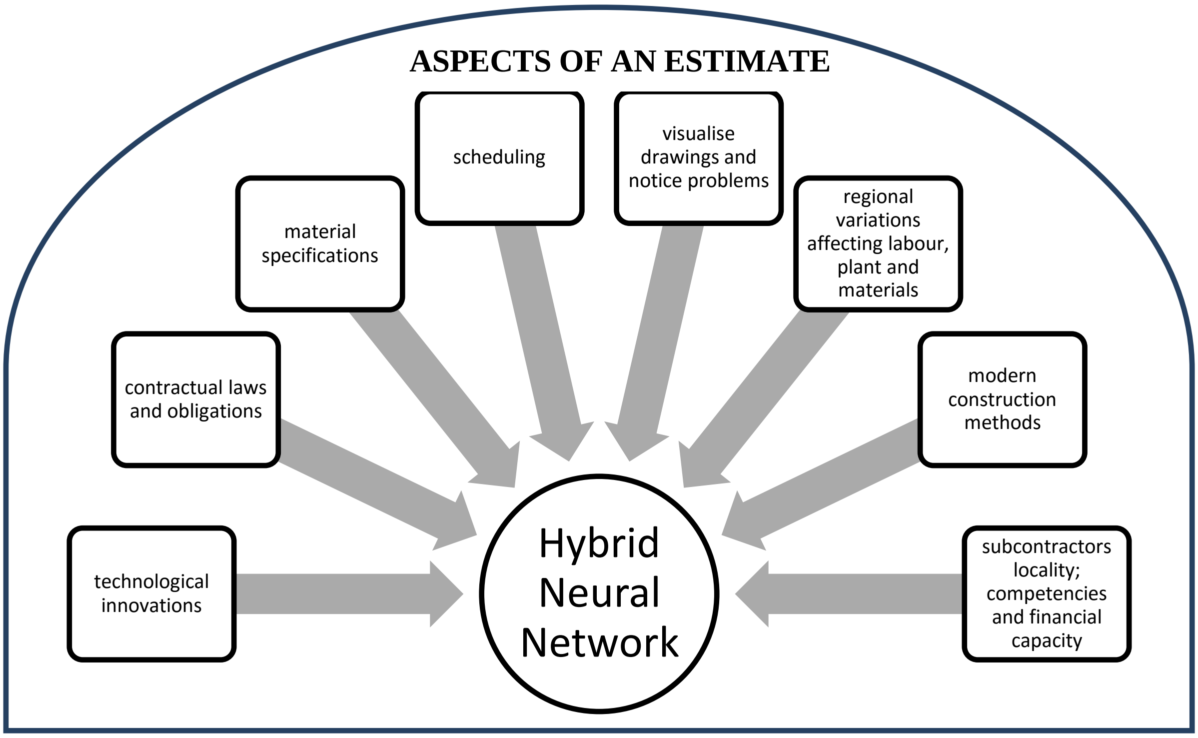


Figure 8.4: Hybrid neural network architecture

The experience of the HNN would be determined from the number of *live* projects fed into the network and the level of prediction accuracy. The HNN should be fed with actual data of each project as it occurs. Actual costs should be compared with the HNN estimates and adjusted accordingly. Then another project, and so on, until the margin of error has been reduced to ±1 percent. Therefore, training of the HNN could take months or years to achieve the recommended margin of error. In comparison to an estimator's experience being linked to the number of years, an HNN experience would be linked to the number of live projects input in terms of epochs. Therefore, an HNN with 20 epochs entails 20 live projects inputs. It is expected that an HNN with 20 epochs will perform better than one with 10.

During training, the HNN should be able to provide solutions to problems. Finally, just as estimators must have the ability to keep historical information on all kinds of costs, including those of labour, material, overhead, equipment, and availability of required items, so must the HNN. When historical data from other projects not used in the training is fed into the HNN, the network should be able to process and present data as at present values. Just as it takes time to train a successful estimator, so it should be with an HNN. It is only when an HNN is adequately trained, then would accurate cost prediction be achieved.

8.6 Summary

Chapter Eight presented the discussion of results of the study into cost estimation to rationalise Zambia's perceived high road infrastructure costs. Literature review, expert opinions and questionnaire results regarding: cost estimation elements; use of indices; and the potential of the UCEM were examined in relation to local and regional validation outcomes. Understanding cost factors provide a formal and documented process for adjusting unit costs for project characteristics and market conditions. The UCEM has the potential to change the contractor selection method in Zambia. The proposed BVS process is based on the contractor with a proficient VfM bid. The UCEM provided a standardised procedure of pricing road activities in Zambia which can set benchmarks for SADC countries. The notion of hybrid neural networks as fifth generation cost estimation was explored. Chapter Nine presents conclusions, recommendations and limitations of the study and highlights areas for further research.

Chapter Nine: Conclusions, Recommendations and Limitations

9.1 Introduction

The previous chapter presented the discussion of results of the study to rationalise Zambia's perceived high road infrastructure costs. Literature review, expert opinion survey adapted from Delphi technique and questionnaire results regarding: cost estimation elements; use of indices; and the potential of the UCEM were examined in relation to local and regional validation outcomes. Understanding cost factors provided a formal and documented process for adjusting unit costs for project characteristics and market conditions. The UCEM has the potential to change the contractor selection method in Zambia. The proposed BVS process based on the contractor with a proficient VfM bid was discussed. The notion of hybrid neural networks as fifth generation in cost estimation was also presented. This chapter presents the conclusions of the study with emphasis on achievement of research objectives. The chapter further highlights recommendations and limitations of the study. Areas for further research are as well outlined.

The overall aim of the research was to develop a construction unit cost estimation model(UCEM) for roadworks incorporating neural networks to provide a standardized procedure of pricing road activities in Zambia and to help understand prevailing market rates in the Zambian construction industry. The specific objectives were to: establish the major cost factors that constitute construction unit rates for road-works in Zambia; determine the appropriate application of the neural network architecture to the established cost factors; investigate unit rate build up from first principles of Southern Africa Transport and Communications Commission (SATCC) pay items; integrate neural network results with first principles build-up in UCEM development; establish a database where variables can be stored and updated when required; and validate the UCEM with other SADC countries that use SATCC specifications.

The aim and objectives were achieved through a robust methodology. Through literature review, factors that influence construction costs were identified. To establish the cost factors, expert opinion and questionnaire surveys were conducted. Firstly, the expert opinion survey adapted from Delphi technique involving seven (7) experts was carried out and results were obtained through Pareto analysis. Then a self-administered questionnaire survey which targeted 84 respondents followed and results were analysed through the SPSS factor analysis.

To determine the cost drivers, expert opinions were used. Expert opinions were sought from key players with wide experience in the Zambian road sector regarding factors that influence unit cost in road-works. Quantification of the established cost factors was determined through the neural network software, NeuroShell2. The Kohonen architecture was used to train the neural network. Establishment of base rate was achieved using first principle equations. Development of the model involved the integration of the neural networked eight cost factors and the base rate to come up with unit rates using ASP.NET 4 with the C# programming language and Microsoft SQL Server 2012 as the database engine. Validation was done locally and regionally using real system measurements. The non-conclusive results from the validation were further subjected to expert intuition.

9.2 Conclusions

The conclusions are discussed in relation to the findings and achievement of objectives.

9.2.1 Establishment of cost factors that affect unit rates for roadworks in Zambia

Eight (8) factors namely: contractor capacity; project location; period of honouring payments; level of design; cost escalation; materials availability; country corruption profile; and political environment were identified as those that most impact unit costs in the Zambian road sector. Cost factors reveal an insight into the construction economic strata of various countries. Analysis of cost factors requires an appreciation of a country’s practices. There are various factors that affect construction costs with varying impacts in different parts of the world. These factors depend on a country’s political, economic, social and technological environment. Periodic review of identified cost factors was essential because of the ever changing political, economic, social and the technological environment of the country.

9.2.2 Determination of economic strata using neural network

Since precise estimation of indirect costs or economic strata is difficult, neural network was used to determine the cost ratio. The established eight (8) factors were analysed using neural network to determine the proportionate breakdown of the cost factors in a given construction unit rate. The Kohonen architecture under the NeuroShell2 software was used because it is unsupervised and has the ability to learn without being shown correct outputs in sample patterns. The Kohonen Self Organizing Map network separated data patterns and predicted that the resulting ratio of the factors, namely, political environment, contractor capacity, period of honouring payments, level of design and cost escalation was 4:2:1:1:1. Therefore political environment was 44 percent of the unit rate followed by contractor capacity at 22 percent and period of honouring payment, level of design and cost escalation each at 11 percent. The uncategorised factors namely: project location; material availability; and country corruption profile (CPI) had minimal impact on unit cost. This was attributed to the constant input nodes of the projects used to train the neural network. For instance, the CPI was the same for all projects because the CPI changes annually and Zambia has been in the same range for the past 5 years. The variation in distance of the sample projects was not high and material availability was normal without severe shortages.

9.2.3 Established base rate for SATCC pay items

The base rate or direct work cost is the accumulation of all necessary input costs for the execution of each unit rate activity. The work items in use in the Zambian road sector are derived from the Southern Africa Transport and Communications Commission (SATCC) Draft Standard Specifications for Road and Bridge Works – September 1998 (Re-printed July 2001). The study observed that the Zambian road sector has modified some of these descriptions to B pay items because of the draft nature of the SATCC specifications. Expected outputs of various types of civil engineering operations and their listed person hours were obtained and used in formulating unit rates from first principles. There are 944 pay items from the SATCC Standard Specifications. Of these, 50 are lump sum items and 50 percent of them fall under series 1000 which deals with preliminary and general items. Apart from pay items whose unit of measurement is lump sum, the base rate for the remaining 854 pay items was calculated from first principles in addition to the 20 B pay items incorporated in the model. Firstly, all-in-labour, material, and equipment and plant rates were built up. These rates were then utilised to establish the base rate of the various pay items. The variance between the base and the prevailing rate represents the economic strata of the unit.

9.2.4 Development of a unit cost estimation model

The model was developed using ASP.NET 4 with the C# (C sharp) programming language with Microsoft SQL Server 2012 as the database engine. The developed UCEM integrated quantitative base costs and quantified cost factors determined by neural network to establish a unit rate. The model outputs are the BoQ descriptions with their associated unit rates. Quantities can be added to the model and the total subjected to value added tax (VAT) to reveal a project cost estimate. The model is standalone and does not use any content management system (CMS). It is web based and can therefore be accessed using any web browser on a personal computer, tablet or mobile phone.

9.2.5 Establishment of a database

The model sets new requirements in the collection of data on road projects. A database where variables can be stored and updated when required was an essential component of the UCEM development. The developed UCEM database can serve as a register of projects in the road sector. The UCEM can store information on the nature, value and distribution of projects. Information regarding the number of on-going projects in any province or countrywide at any given time would be readily available. The UCEM database can be used in the establishment of an official road sector library whose information could be accessed online. A small fee could be charged for maintenance of the database.

9.2.6 UCEM validation

Validation of the UCEM was done using a two-step process. Firstly, the model was validated locally using data from five projects from the Zambian road sector which were not utilised in the neural network training. The second step involved validating the model regionally with project data from the three (3) SADC countries namely Malawi, South Africa and Zimbabwe.

Results obtained from local validation were varied and did not provide conclusive results. It was difficult to justify any of the unit rates presented from the real projects locally. Therefore, the UCEM rates were subjected to further validation using expert intuition. Two experts were identified. They did not go through all the rates but applied the Pareto Principle which states that approximately 80 percent of the project cost is contained in 20 percent of the items. Unit rates under series 3000 and 4000 were examined. The experts were not concerned so much with the unit rate derived by the model but rather the first principles equations and assumptions made.

Regional validation which relied on real system measurements as well as theoretical results analysis revealed that unit rates in the Zambian road sector were three times higher than those in South Africa and twice the Malawian estimates. This was consistent with literature which showed that the cost of fuel and cement were higher in Zambia compared to South Africa and Malawi. Therefore, the model was functioning correctly as the derived unit rates obeyed the operational laws provided for the assumptions. However, unit rates from Zimbabwe suggested that further investigation into the detailed behaviour of the model would be necessary.

9.3 General recommendations

Arising from the above conclusions, the following are the main recommendations directed at standardizing the procedure of pricing road activities and providing value for money in infrastructure delivery in the Zambian road sector:

a) adoption of a cost classification system to benefit from the UCEM is recommended. The classification guideline would be used for preparation of cost estimates and classifying the accuracy level expected from the estimates and the level of risk associated with estimates;

b) establishment of construction specific indices in terms of bidding, material prices, labour and equipment productivity is also recommended. Data stored by the UCEM for labour, plant and material for first principles estimating can be used to derive construction cost indices (CCI) that could be used in the Zambian road sector. Stakeholders are urged to initiate local site productivity studies to be published annually to monitor road sector output rates;

c) make it mandatory for Engineers' Estimates computed using the UCEM to be deposited as one of the bids in the tender box at each tender session;

d) adoption of the best value selection (BVS) method in procurement of works in the Zambian road sector be adopted. Because the engineers estimate is known, only bids within ±25 percent would be evaluated. The contractor with the lowest VfM score would be best value evaluated bidder. The VfM score is obtained from the total corrected bid amount divided by the project specific indicator (PSI) score;

e) standardisation of road furniture such as road signs, marker posts, kilometre posts and guard rails in the Zambian road sector. This could allow for comparative analysis of series 5000 unit rates across various projects in the sector;

f) revision of the SATCC specification which are still in draft form to ensure that the method of measurement is responsive to the Zambian road sector.

g) adoption of the UCEM labour method (ULM). This is the UCEM standardised method of calculating the all-in labour rate for the Zambian road sector;

h) requirement for periodic quantification and revision of cost factors. A standardised economic strata questionnaire survey would be included as part of the contractors' and consultants' certificates and licenses renewal process. The information gathered would result in revised cost factors comparable with the Zambian road sector environment changes. The review can be done every five (5) years; and

i) establishment of a road sector database library where variables can be stored and updated when required. The information required is a lot and varied; therefore, organisations such as the Association of Building & Civil Engineering Contractors (ABCEC) would have to be mandated to provide some of this information. Furthermore, the database can serve as a register of projects where information on the nature, value and distribution of projects is stored. The database could be accessed online at a fee;

9.4 Limitations of the study

The study had limitations that need to be taken into consideration when interpreting the reported findings.

a) Lack of official current publication of productivity data for the Zambian road sector and absence of construction cost indices led to the use of data for similar works from other countries. Industry accepted data resources such as RS Means Heavy Construction Cost Data, Spon's Civil Engineering and Highway Works Price Book 2014 were used. However, such data was used with caution for adoption to the Zambian road sector.

b) Limited training data. Since the creation of the Road Development Agency (RDA) in 2002, it is believed that more than 2000 projects have been executed in the road sector. There is no official publication on the exact number of projects executed by the RDA. The estimate of 2000 projects was calculated during data collection. The official number of projects given for this study was 254 accounting for approximately 12 percent of road projects used to train the neural network.

c) Local validation using real systems measurement was inconclusive. Direct comparison of UCEM rates to existing BoQ rates across projects did not provide indicative rates of the pay items. This could be attributed to contractors' business trade secrets in pricing such as front loading, quantity sensitivity and activity probability.

d) The Kohonen architecture is one of the least used neural network architecture and literature on its use in neural network research studies was limited. Therefore, more expertise is required in the interpretation of the results. One of the ways this can be achieved is through publications and conference proceedings dedicated to artificial intelligence.

e) it was not clear as to which software package 'was commonly used' by Zambian Contractors

9.5 Further research

While significant steps have taken place in recent years in ensuring VfM, serious vulnerabilities remain. Improvements in data availability and mathematical techniques allow for more in-depth study of cost forecasts as it is seen as one of the critical project success factors. Because of time, scope and financial constraints the areas stated below are suggested as subjects for further research.

a) The percentage of material wastage on site included in the base rate was from literature and not specific to the Zambian road sector sites. Detailed studies are recommended in order to establish material wastage specific to Zambia.

b) Due to lack of data on mobilisation costs, lump sum costs were not priced in the UCEM. Instead, a provision was made for an estimator to insert a project specific sum. There have been no detailed studies carried out regarding mobilisation costs on road projects in Zambia. Research to accurately calculate the preliminary and general items percentage should be encouraged. Consideration regarding: location; complexity; specialized equipment requirements; type of work being performed; rural versus urban projects with multiple work sites; excessive preparatory removal items; and weather patterns investigated to provide consistent guidelines. This would further reduce costs for the lump sum items which are typically bid at higher costs than quantified activities.

c) One of the eight established factors, political profile relates to political interference as perceived by stakeholders. It was a challenge to quantify the risk associated with this factor. Thus the neural network input nodes for this factor were generic. Further studies would be required to ensure that the quantified risks used for the neural network input nodes are specific to the Zambian scenario.

d) Economies of scale were not taken into account in the UCEM. Contractors tend to lower the rate of items with high quantities as compared to those with low quantities so that the tendered sum is competitive. Sometimes very large quantities of certain materials could cause an increase to the unit bid rate. For example, the price of cement could go up due to increased demand arising from planned large structures. No studies have been carried out in Zambia to determine at what point a road project would attain constant returns to scale.

e) it was not clear as to which software package 'was commonly used' by Zambian Contractors

9.6 Contribution to the body of knowledge

The gap between the knowledge of what works and the widespread adoption of those practices has become a major preoccupation of researchers and a challenge for funders and policy makers (Baker, 2011). The essence of research is to add to the existing body of knowledge. Chidi (2013) stated that there were four (4) ways to contribute to the body of knowledge namely: through the research area; methodology used; solving trending issues; and developing a unique approach or model.

i. Through the research area

This research focused on the development of a construction unit cost estimation model. This, in itself was a unique process which considered all 944 pay items used in the Zambian road sector to establish unit rates.

ii. Methodology used

The methodology incorporated neural network prediction. So far, most studies on neural networks have focused on deriving conceptual estimates. In this study, the focus was on integrating neural network prediction with unit rate build up from first principles to derive definitive estimates for SATCC pay items. This is the first time neural networks have been used in the Zambian road sector.

iii. Solving trending issues

It is hoped that the UCEM could provide a standardized procedure of pricing road activities in Zambia and in turn help understand the prevailing market rates in the Zambian construction industry. The UCEM could assist road authorities to develop engineer's estimates and formulate annual work plans in a shorter period.

iv. Developing a unique approach or model

The model sets new requirements in the collection of data on road projects. This could in turn lead to the revision of various tender and contract documentation practices. It is hoped that the UCEM provides a milestone in the development of the *next generation* road and bridge management system in Zambia.

9.6.1 Validity, reliability and generalisability

Validity, reliability and generalisability can only be prudently discussed in the context of the research method undertaken. Even though this study adopted a mixed method approach, it was skewed towards a positivist paradigm. The three key concepts of validity, reliability and generalisability in quantitative methods have to do with measurement. Quantitative research is about measuring something. Therefore, ontology, epistemology and methodology consider objectivity, observable facts and independence from researcher.

i. Validity

Hammersley (1987) states that an account is valid or true if it represents accurately those features of the phenomena, that it is intended to describe, explain or theorise. One test of validity is making the results confirmable. The formulae used in the UCEM can be checked and confirmed objectively.

ii. Reliability

Reliability or replicability considers whether the means of measurement are transferrable (Winter, 2000). The developed UCEM can be replicated and used in determining unit costs of various infrastructure projects.

iii. Generalisability

The ability to generalise findings to wider groups and circumstances is one of the most common tests of validity for quantitative research (Winter, 2000). Generalisability focuses on external validity in quantitative research. Generalisability describes the extent to which research findings can be applied to settings other than that in which they were originally tested. A positivist approach favour generalisations leading to predictions. The UCEM generalisability leads to prediction of unit costs of various work activities. External validation in the research was achieved through local and regional validation of the model.

9.7 Summary

The Government of the Republic of Zambia continues to invest in the construction of roads in all geographical regions of the country which have different topographical setups. The different regions have varied sources of materials and climatic conditions that may affect road activities pricing. To achieve VfM in road infrastructure delivery, it is necessary to standardise cost estimation methods of road activities.

The UCEM has the potential to provide consistent and uniform estimating and pricing procedures in the road sector through a harmonised methodology responsive to new construction environments. By computing the engineers' estimates, the best value selection process can be used to achieve VfM. The UCEM can be used for planning and negotiation purposes and also for monitoring the escalation of unit prices in the road sector. Its database can be used as a register of projects. Access to the UCEM database can lead to standardised guidelines for regulating the Zambian road sector.

It is hoped that the UCEM will: create improvements in the cost estimation of infrastructure projects; establish benchmarks in the alignment of work practices; permit the on-going development of best practices in cost estimation to become more effective; and become an indispensable management tool for all.

References

AACE International (2011) Recommended Practice No. 17R-97, *Cost Estimate Classification System*, TCM Framework: 7.3 – Cost Estimating and Budgeting The Association for the Advancement of Cost Engineering (AACE)

AACE International (2013) *Cost Engineering Terminology, Recommended Practice No. 10S-90, TCM Framework: General Reference,* The Association for the Advancement of Cost Engineering (AACE)

Akitoye, A. (2000) *Analysis of factors influencing project cost estimating practice*, Construction Management and Economics, 18 (1): 77-89.

Al-Tabtabai H., Alex P. A., and Tantash M. (1999) *Preliminary Cost Estimation of Highway Construction Using Neural Networks*, Cost Engineering 41, (3) p. 19-24

Association of Building & Civil Engineering contractors (ABCEC) (2013) *Joint Industrial Council Collective Agreement for the period 1st January 2014 to 31 December 2015*, ABCEC

Association of Southern African National Road Agencies (ASANRA) (2008) *Standards and Technical Specification for Infrastructure and Equipment, ASANRA*

Associated General Contractors (AGC) of America (2008) *AGC Construction Inflation Alert* available online at *http://www.pmmag.com/ext/resources/PM/Home/Files/PDFs/0308ConstructionInflationAlert.pdf* [accessed 15 April 2015]

Ayed A. S. (1997) *Parametric Cost Estimating of Highway Projects using Neural Networks*, MEng Unpublished thesis, Memorial University of Newfoundland, Canada

Baker, G. R. (2011) *The contribution of case study research to knowledge of how to improve quality of care.* BMJ Quality & Safety, 20(Suppl_1), i30–i35. doi:10.1136/bmjqs.2010.046490 available online at http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3066793/ [accessed 22 March 2014]

Bakhary N., Khairulzan Y. and Ng C. N. (2004) *Univariate Artificial Neural Network in Forecasting Demand of Low Cost House in Petaling Jaya*, Jurnal Teknologi, 40 (B) p 1–16

Bates R. H. and Collier P. (1994) *The Politics and Economics of Policy Reform in Zambia. Policy Reversal in Zambia, 1985*-1987 available online at http://www.galbithink.org/topics/cred/przam.htm [accessed 21 April 2015]

Black J. (1984) *Application of Parametric Estimating to Cost Engineering*, AACE Transactions, The Association for the Advancement of Cost Engineering (AACE)

Blaxter L., Christina H. and Malcolm T. (2001) *How to research 2nd Edition*, Open University Press ISBN 0–335–20903–3

Blocher E. J, Stout D. E, Cokins G. and Chen K. H. (2008) *Cost Management: A Strategic Emphasis (4ed)*, The McGraw-Hill Companies, Inc., ISBN: 0073128155

Bode, J. (1998) *Neural Networks for Cost Estimation*, Cost Engineering Journal 40 (1) p. 25-30

Brewerton P. and Millward L. (2001) *Organizational Research Methods* London: Sage Publications

Butts G. (2007) *Escalation: How Much is Enough?* AACE International Transactions Morgantown, WV: AACE International

Canadian Construction Association - Joint Federal Government / Industry Cost Predictability Taskforce (2012) *Guide to Cost Predictability in Construction: An Analysis of Issues Affecting the Accuracy of Construction Cost Estimates* available online at www.cca-acc.com/pdfs/en/CCA/Guide_to_Cost_Predictability.pdf [accessed 05 November 2013]

Central Statistical Office (CSO) (2014) *Zambia in Figures: 1964 – 2014*, Government of the Republic of Zambia

Chidi R. (2013) *4 Ways you can contribute to the Body of Knowledge* available online at http://researchclue.com/blog/ways-to-contribute-to-the-body-of-knowledge.html [accessed 22 March 2015]

Chudley R. and Greeno R. (2014) *Building Construction Handbook 10th Edition*, Routledge UK ISBN 13: 978-0-415-83638-8 Pg 129

Cohen L., Manion L. and Morrison K. (2000) *Research Methods in Education* (5th ed.), Routledge Palmer

Construction Industry Development Board (CIDB) South Africa (2015) *Invitation to Tender: Study of the Drivers of Construction Costs for the CIDB RFB20120* available online at http://www.cidb.org.za/Documents/SCM/scm-amended-bid-invite-rfb20120-august-2015.pdf [accessed 17 August 2015]

Cooper D. R. and Schindler P. S. (2011) *Business Research Methods* 11th ed., McGraw Hill, pp.390-397

Corbin J. and Strauss A. (2008) *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory*, SAGE Publications, California, ISBN 1412906449

Creative Research Systems (2014) *Sample Size Formula*, available online at http://www.surveysystem.com/sample-size-formula.htm [accessed on 09 April 2014]

Creese R. C. and Li L. (1995) *Cost Estimation of Timber Bridges Using Neural Networks.* Cost Engineering Vol. 37 / No. 5 AACE International

Creswell, J. W. (2003). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches (2nd ed.)*, Sage Publications, California.

De la Garza, J. and Rouhana K. (1995) *Neural Network versus parameter-based application*, Cost Engineering, AACE International, 37 (2) p.14-18.

De Winter J. C. F., Dodou D. and Wieringa P. A. (2009) *Exploratory Factor Analysis with Small Sample Sizes*, Multivariate Behavioral Research, 44, 2009, pp147–181

Department of Energy (DOE) (2011) *Cost Estimating Guide G 413.3-21* U.S. Department of Energy, Washington, Available online [accessed 09 August 2014]

Division of Roads and Transport Technology, CSIR (1998) *Standard Specifications for Road and Bridge Works*, Southern Africa Transport and Communications Commission (SATCC)

Econtech Pty Ltd (2007) *Economic Analysis of Building and Construction Industry Productivity*, Office of the Australian Building and Construction Commissioner

Elinwa A. U. and Buba S. A. (1993) Construction cost factors in Nigeria, Journal of Construction Engineering and Management. 119 (4), p 698-713

Emerson, H. (1911) *The Twelve Principles of Efficiency*. New York: The Engineering magazine. available online at http://babel.hathitrust.org/cgi/pt?id=bc.ark:/13960/t2g746111 [accessed 04 July 2015]

Emsley M. W., Lowe D. J., Duff A. R., Harding A. and Hickson A. (2002) *Data modelling and the application of a neural network approach to the prediction of total construction costs;* Construction Management and Economics (20) p. 465–472 available online http://www.tandf.co.uk/journalsDOI: 10.1080/01446190210151050 [accessed 16 January 2014]

Energy Regulation Board (2015) *Fuel Retail Prices* available online at http://www.erb.org.zm/content.php?viewpage=tfpg [accessed 25 April 2015]

Enshassi A., Sherif M. and Ibrahim M. (2007) *Contractors' Perspectives towards Factors Affecting Cost Estimation in Palestine*, Jordan Journal of Civil Engineering, 1 (2) 186-193

Elbeltagi D. E. (2015) *Cost Estimating – Chapter 3* available at: http://osp.mans.edu.eg/elbeltagi/Cost%20Ch3.pdf [Accessed 13 January 2016]

Florida Department of Transportation (FDOT) (2010) *Guideline for establishing construction contract duration*, Florida, USA.

Flyvbjerg B. (2006) *From Nobel Prize to Project Management: Getting Risks Right*. Project Management Journal, vol. 37, no. 3, pp. 5-15 available online at http://flyvbjerg.plan.aau.dk/Publications2006/Nobel-PMJ2006.pdf [accessed 22 May 2015]

Garson D. (1998) *Neural Networks: An Introductory Guide for Social Scientists*, London: Sage Publications: ISBN 0-761-95731-6

Geddes S. (1960) *Estimating for Building and Civil Engineering Works 2nd Edition*, London: George Newnes Limited

Ghosh B. N. (2011) *Scientific Method and Social Research (4th ed.)* Sterling Publishers Pvt. Ltd, New Delhi ISBN 978-81-207-5790-5

Government of the Republic of Zambia (GRZ) (2014), *Zambia Distance Table* Government Printers, Zambia

Government of the Republic of Zambia (GRZ), (2010), *Sixth National Development Plan 2011 - 2015*, Government printers, Zambia

Government of the Republic of Zambia (GRZ), (2012), *GRZ Budget 2013*, Government printers, Zambia

Hammersley M. (1987) *Some Notes on the Terms 'Validity' and 'Reliability'* British Educational Research Journal, 13: 73–82. doi:10.1080/0141192870130107

Harber A. M. (1988) *Survey of productivity rates used for highway construction.* A report presented to the graduate committee of the department of civil engineering, University of Florida.

Hasan A. J. (2013) *Parametric Cost Estimation of Road Projects Using Artificial Neural Networks*, M.Sc. Unpublished thesis, The Islamic University, Gaza

Hawley S. (2004) *Financing corruption? The role of Multilateral Development Banks and Export Credit Agencies* International Finance and Corruption Global Corruption Report 2005, Transparency International

Hendrickson C. (2008) *Project Management for Construction, Fundamental Concepts for Owners, Engineers, Architects and Builders* available online at http://pmbook.ce.cmu.edu/ [accessed 05 November 2013]

Herbsman Z. J. and Ellis R. D. (1995) *NCHRP Synthesis of Highway Practice 215: Determination of Contract Time for Highway Construction Projects,* Transportation Research Board, National Research Council, Washington, D.C.

Hillston J. (2003) *Model Validation and Verification University of Edinburgh* School of Infomatics available online at http://www.inf.ed.ac.uk/teaching/courses/ms/notes/note14.pdf [accessed 9 March 2015]

Holroyd T. M. (2000) *Principles of Estimating* ISBN 072772763X, Thomas Telford, London available online at https://mitpress.mit.edu/books/understanding-media [accessed 26 June 2015]

ILO/ASIST (1998) *Productivity Norms for labour-based construction*, ASIST Information Service Technical Brief No. 2

Japan International Cooperation Agency (JICA) (2009) *The Study on Comprehensive Urban Development Plan for the City of Lusaka in the Republic of Zambia,* Japan International Cooperation Agency.

Jiang Y. and Wu H. (2004) *Determination of INDOT Highway Construction Production Rates and Estimation of Contract Times,* Department of Building Construction Management, Purdue University, Indiana, USA.

Johnson B. R and Onwuegbuzie J. A (2004) *Mixed Methods Research: A Research Paradigm Whose Time Has Come,* Educational Researcher 33 (14) DOI: 10.3102/0013189X033007014 available online at http://edr.sagepub.com/content/33/7/14 [accessed 17 January 2014]

Kratz R. A. (1992) *A comparison of the Delphi technique with the nominal group technique (NGT) in determining the criteria to be used for measuring the value-added effect of associate degree graduates of two Pennsylvania community colleges* Dissertations available from ProQuest. Paper AAI9224774.available online at http://repository.upenn.edu/dissertations/AAI9224774 [accessed 02 March 2015]

Kaela L. C. W. (2004) *National Governance Baseline Survey: Report 2004*, Department of Political and Administrative Studies, University of Zambia

Krzysztof S. and Bozena H. (2007) *Mathematical- neural model for assessing productivity of earthmoving machinery,* Journal of Civil Engineering and Management, 13:1, 47-54 available online at http://dx.doi.org/10.1080/13923730.2007.9636418 [accessed 16 January 2014]

Kumar R. (2005) *Research Methodology-A Step-by-Step Guide for Beginners,* (2nd.ed.), SAGE Publications, New Delhi, ISBN 1412911949

Langdon D. (2014) Spon's Civil Engineering and Highway Works Price Book 2014, Spon Press, 2014

Leming M. R. (1997) *Research and Sampling Designs: Techniques for Evaluating Hypotheses* available online at: http://www.stolaf.edu/people/leming/soc371res/research.html [accessed 20 January 2014]

Linstone H. A. and Turoff M. (2002) *The Delphi Method: Techniques and Applications (Ed.)* available online http://is.njit.edu/pubs/delphibook/[accessed 02 March 2015]

Mackenzie N. & Knipe S. (2006). *Research Dilemmas: Paradigms, methods and methodology*, Issues in Educational Research, 16(2), 193-205 available online at http://www.iier.org.au/iier16/mackenzie.html [accessed 17 January 2014]

Markets and markets.com (2013) *Heavy Construction Equipment Market: By Types (Earthmoving, Material Handling, Heavy Construction Vehicles, Others), Application Areas (Infrastructure, Commercial, Residential), and Geography - Global Trends & Forecast To 2018 (Report Code: ED 2079)* available online at http://www.marketsandmarkets.com/Market-Reports/heavy-construction-equipment-market-1211.html [accessed 08 September 2014]

Mashilipa J. (2004) *An investigation on the effects and their implications of using British outputs in Estimating in the Zambian Construction Industry,* BSc (Building) Unpublished thesis, Copperbelt University, Zambia

Mbongwe T., Nyagol B. O., Amunkete T., Humavindu M., Khumalo J., Nguruse G. and Chokwe E. (2014), *Understanding competition at the regional level: an assessment of competitive dynamics in the cement industry across Botswana, Kenya, Namibia, South Africa, Tanzania and Zambia*, available online at http://www.africancompetitionforum.org/sites/default/files/docs/Cement_ACF_short ICNConf_paper_16042014.pdf [accessed 16 April 2015]

Memon A. H., Rahman I. A., Abdullah M. R. and Azis A. A. (2010) *Factors Affecting Construction Cost Performance in Project Management Projects: Case of Mara Large Projects*, Proceedings of Post Graduate seminar on Engineering, Technology and Social Science. 29-30 November 2010, Universiti Tun Hussein Onn Malaysia

Ministry of Roads (2011) *Cost Estimation Manual for Road Maintenance Works,* Republic of Kenya

Ministry of Works and Supply - ILO/ASIST (2004) *Contractor's Handbook for Labour-Based Road Works*, Roads Department, Roads Training School, Government of the Republic of Zambia

Molenaar K., Anderson S. and Schexnayder C. (2011) *AASHTO Practical Guide to Estimating*, National Cooperative Highway Research Program (NCHRP) Project 20-07/Tasks 278 and 308

Moselhi O., (2003) *Estimating the Cost of Change Orders.* Cost Engineering Vol. 45, No. 8AACE International

Moselhi O. and Siqueira I. (1998) *Neural Networks for Cost Estimating of Structural Steel Buildings*, AACE International Transactions

Mpofu R. and Munalula T. (2012) *Potential scalability of a methodologically harmonized consumer price index in Africa,* The African Statistical Journal, Volume 14, p105-118 available online at http://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/ASJ_vol14%20Sta4%20Eng.pdf [accessed 26 June 2015]

Multilateral Investment Guarantee Agency (2014) *2013 World Investment and Political Risk*, The World Bank Press ISBN (electronic): 978-1-4648-0146-4 DOI:

10.1596/978-1-4648-0039-9 available online at http://www.miga.org/documents/WIPR13.pdf [accessed 25 April 2015]

Muqeem S., Idrus A., Khamidi M. F., Ahmad J. B. and Zakaria S. B. (2011) *Construction labor production rates modeling using artificial neural network*, Journal of Information Technology in Construction (ITcon), Vol. 16, pg. 713-726, available online at http://www.itcon.org/2011/42 [accessed on 09 April 2014]

Muya M., (1999) *A Systematic Approach for Improving Construction Material Logistics* Unpublished PhD thesis, Loughborough University

Muzamil B. A. and Khurshid A. (2014), *Analysis of Labour Productivity of Road Construction in Pakistan*, International Journal of Engineering and Advanced Technology (IJEAT), Volume 3, Issue 3.

National Audit Office (2014) *Successful commissioning toolkit* available online at http://www.nao.org.uk/successful-commissioning/general-principles/value-for-money/assessing-value-for-money/ [accessed 26 June 2015]

National Council for Construction (NCC) (2010) *Unit Rates in the Zambian Construction Industry*, Construction News Volume 1, Issue 3 p1,3

Neville C. (2007) *An Introduction to Research & Research Methods*, Effective Learning Service School of Management, University of Bradford, available online at www.bradford.ac.uk/management/els [accessed 15 January 2014]

O'Brien R. (2001). *An Overview of the Methodological Approach of Action Research*, Faculty of Information Studies, University of Toronto, available online at http://www.web.ca/~robrien/papers/arfinal.html [accessed 20 January 2014]

Oxford Advanced Learner's Dictionary 9th Edition (2014) Oxford University Press ISBN-13: 978-0194799485

Parkinson N. C. (1962) *Parkinson's Law: and other studies in administration*, Houghton Mifflin

Peško I., Trivunić M., Cirović G., Mučenski V. (2013) *A preliminary estimate of time and cost in urban road construction using neural networks* Technical Gazette 20 (3), 563-570 [accessed 16 January 2014]

Pozzo R. (2004) *The Impact of Aristotelianism on Modern Philosophy* CUA Press p.41. ISBN 0-8132-1347-9

Prokopenko J. (1987) *Productivity Management*, International Labour Office, Geneva.

Raballand G. and Whitworth A. (2012) *The Crisis in the Zambian Road Sector*, Working Paper No. 5, Zambia Institute for Policy Analysis and Research (ZIPAR), 2012, Lusaka.

Raddon A. (2014) *Early Stage Research Training: Epistemology & Ontology in Social Science Research*, Centre for Labour Market Studies, College of Social Science, University of Leicester available online at http://www2.le.ac.uk/colleges/socsci/documents/research-training-presentations/EpistFeb10.pdf [accessed 17 January, 2014]

Road Development Agency (RDA) (2010) 2009 Annual Report, RDA

Road Development Agency (RDA) (2009) *Cost Based Unit Rate Analysis and Design Review of District Roads Projects in Luapula and Western Provinces of Zambia* Unit Rate Analysis Report Draft-2, RDA

Road Development Agency (RDA) (2012) *Request letter for compilation of unit cost for road works* dated 19th November and signed by the Chief Executive Officer.

Road Development Agency (RDA) (2012a) *Roads Magazine* January- June 2012, Edition No. 5, RDA

Road Development Agency (RDA) (2012b) 2013 Road Sector Annual Work Plan, RDA

Rubin A. and Earl B. (2010) *Essential Research Methods for Social Work Second Edition*, Cengage Learning Inc. ISBN 13: 978-0-495-60437-2

SADC (2012a) *Transport Sector Plan, Regional Infrastructure Development Master Plan*, Southern African Development Community

SADC (2012b) *2011 Statistical Yearbook, Statistics on Major Industry Groups* available online at http://www.sadc.int/information-services/sadc-statistics/sadc-statiyearbook/ [accessed 26 June 2015]

Setyawati B. R., Sidharta S., and Creese R. C., (2003) *Neural Networks for Cost Estimation*, AACE International Transactions

Sidhu K. S. (2006) *Methodology of Research in Education*, Sterling Publishers Pvt. Ltd, New Delhi ISBN 978-81-207-0101-4

Smith S. W. (1997) *The Scientist & Engineer's Guide to Digital Signal Processing* 1st Edition available online at http://www.dspguide.com/ch26/2.htm [accessed 04 May 2015]

Smith A. E. and Mason A. K. (1997) *Cost Estimation Predictive Modeling: Regression versus Neural Network.* Engineering Economist 42, (2) 137-161.

Steyn H., Basson G., Carruthers M., Du Plessis Y., Prozesky-Kuscke B., Kruger D., Van Eck S. and Visser K. 2006. *Project management: A multi-disciplinary approach*. Pretoria: FPM Publishing, p 173

Swarup N. (2008) Construction Cost Indices, Construction Industry Development Council, India available online at http://www.cea.nic.in/reports/hydro/...cidc.../presentation_cost_%20indices.pdf [accessed 02 September 2013]

Times of Zambia (2010) *National Council for Construction, Expressions of Interest to carry out a study on Construction Unit Rates in Zambia under World Bank funding to RoadSIP II* Times of Zambia, 10th March

Times of Zambia (2013) *Zambia Public Procurement Authority, Expressions of Interest to undertake an assessment of the prevailing market rates in the construction industry* Times of Zambia, 16th August. p13

Trochim W. M. K. (2006) *Research Methods Knowledge Base* available online at http://www.socialresearchmethods.net/kb/evaluation.php [accessed 20 January 2014]

Trombka A. and Downey S. (2008) *A Study of County Road Project Cost and Schedule Estimates,* Office of Legislative Oversight, Montgomery County, Maryland Report Number 2008-04 available online at https://www.montgomerycountymd.gov/olo/resources/files/2008-4.pdf [accessed 05/07/2014]

Universal Mining & Chemical Industries Ltd (UMCIL) (2015) available online at http://www.umcil.co.zm/products.html [accessed 5 May 2015]

University of Southampton (2014) *eResearch Methods – Strategies and Models* available online at http://www.erm.ecs.soton.ac.uk/theme4/models.html [accessed 22 February, 2014]

Varga-Atkins T., Bunyan N., McIsaac J. and Fewtrell J. (2011) *The Nominal Group Technique: a practical guide for facilitators Version 1.0.* University of Liverpool available online at: http://www.liv.ac.uk/cllserver/resource-database-uploads/pdf/guide_for_ELESIG_v1.pdf [accessed 02 March 2015]

Vojinovic Z., Seidel R., and Kecman V. (2000) *Advanced Cost Estimating and Strategic Planning,* AACE International Transactions. Morgantown, WV: AACE International

Walliman N. S. R. (2001) *Your Research Project: A Step by Step Guide for the First Time Researcher,* London, Sage Publications.

Ward Systems (2014) *Classic NeuralShell2 Manual* available online at http://www.wardsystems.com/manuals/neuroshell2/ [accessed 12 August 2014]

Welman J. C. and Kruger S. J. (2001) *Research Methodology for the Business and Administrative Sciences 2nd Edition* Cape Town: Oxford University Press Southern Africa

Wilkinson D. (2005) *The Essential Guide to Postgraduate Study.* London: Sage Publications

Winter G. (2000) *A comparative discussion of the notion of 'validity' in qualitative and quantitative research* The Qualitative Report 4(3/4) available online at: http://www.nova.edu/ssss/QR/QR4-3/winter.html [accessed 05 September 2016]

Wisker G. (2001) *The Postgraduate Research Handbook: Succeed with your MA, MPhil, EdD and PhD*. China: Palgrave Macmillan, p 190

World Bank (2014) *World Governance Indicators (1996-2013)* available online at http://info.worldbank.org/governance/wgi/index.aspx#doc [accessed 25 April 2015]
World Bank (2015) *Country Classification by Income* available online at http://data.worldbank.org/about/country-and-lending-groups [accessed 10 April 2015]

Wright L. W. (1995) *Qualitative International Management Research*, in Punnett, B.J. and Shenkar, O., (eds.) Handbook for International Management Research, Blackwell, Oxford.

Yi W. and Chan A. (2013) *Critical Review of Labor Productivity Research in Construction Journals*, Journal of Management in Engineering, doi:10.1061/(ASCE)ME.1943-5479.0000194.

Yousuf M. I. (2007) *Using Experts' Opinions through Delphi Technique* Practical Assessment Research & Evaluation, 12(4) available online: http://pareonline.net/getvn.asp?v=12&n=4 [accessed 02 March 2015]

Zambia Public Procurement Authority (ZPPA) (2014) *Consulting services to undertake an assessment of the prevailing market rates in the construction industry,* Request for proposals, ZPPA, Zambia

Zambian Economist (2014) *Fiscal Decentralisation in Zambia* available online at http://www.zambian-economist.com/2014/07/fiscal-decentralisation-in-zambia.html [accessed 17 August 2015]

Appendices

Appendix A: Sample of research instrument – questionnaire

QUESTIONNAIRE

DEVELOPMENT OF A UNIT COST ESTIMATION MODEL FOR ROADWORKS IN THE ZAMBIAN CONSTRUCTION INDUSTRY

To develop a unit cost estimation model, factors that affect unit cost in the construction of roads need to be established. In Zambia it is not clear what these cost factors are.

A. GENERAL INFORMATION

1. Name of employer / business ....

2. What is your current position in your organisation (*please tick*)?

   Junior management ☐ Middle management ☐ Senior management ☐

3. Which construction sub-sector do you belong to (*please tick*)?

   Clientele ☐ Consultancy ☐ Manufacturing ☐ Supply ☐ Contractor ☐ Other (*State*)………………. ☐

4. What is your highest level of education (*please tick*)?

   Form V /Grade 12 ☐ Diploma ☐ Bachelors Degree ☐ Masters Degree ☐ Doctorate ☐

5. How many years of experience do you have in the construction industry (*please tick*)?

   None ☐ Less than 5 years ☐ Between 6 – 10 years ☐ Between 11 – 20 years ☐ more than 20 years ☐

6. Do you have any knowledge in computing Bill of Quantity (BoQ) unit rates (*please tick*)?

   Yes ☐ No ☐

7. If yes in 6 above, how did you acquire knowledge in rate build up? Through

   Formal training ☐ On job training ☐ Not applicable ☐ other (please state)…………………………………… ☐

8. How does your organisation come up with BoQ rates?

   ☐ First principle (build up rate manually)
   ☐ Historical (use rates from previous tenders with some adjustment factor)
   ☐ Computer software (please state)……………………………………
   ☐ Own estimating experience

B. PLANT AND EQUIPMENT

9. Is plant and equipment required for road construction readily available in Zambia (*please tick*) ?

   Yes ☐ No ☐ Not sure ☐

10. From your experience, what is the state of construction plant and equipment in Zambia (*please tick*)?

   Very Poor ☐ Poor ☐ Average ☐ Good ☐ Excellent ☐ Not sure ☐

11. Is the equipment your organisation uses owned or hired (leased) (*please tick*)?

Owned ☐ Hired ☐ Not sure ☐ Not applicable ☐

	No impact	Low Impact	Moderate Impact	High Impact	Very High Impact
12. How do you rate the effect of plant and equipment on project **cost**?					
13. How do you rate the effect of plant and equipment on project **completion**?					
14. How do you rate the effect of plant and equipment on project **quality**?					

C. LABOUR

15. From your experience, how is the performance of construction workers in the Zambian construction industry (*please tick*)?

Very Poor ☐ Poor ☐ Average ☐ Good ☐ Excellent ☐ Not sure ☐

16. How is the performance of local construction workers in comparison to foreign construction workers in your opinion (*please tick*)?

Very Poor ☐ Poor ☐ Average ☐ Good ☐ Excellent ☐ Not sure ☐

17. Does the type of construction workers on site (that is whether local or foreign) have an effect on the unit cost rates (*please tick*)?

Yes ☐ No ☐ Not sure ☐

18. Indicate availability of various categories of workers normally found on project sites in the Zambian construction industry (*please tick*)?

Category of workers	Not sure	Low	Moderate	High	Very High (Readily available)
Professional workers (engineers, surveyors etc.)					
Skilled workers (Technicians, foremen etc.)					
Semi-skilled (Equipment operators etc.)					
Unskilled (general workers)					

Performance levels or output rates are standards or benchmarks for a particular sector for example a bricklayer can lay 1.06m^2 per hour

19. Are you familiar with output rates or performance levels for each activity carried out by various category of workers on site (*please tick*)?

Yes ☐ No ☐ Not sure ☐

20. Would production on site improve if performance levels for each activity carried out by various category of workers was made available (*please tick*)?

Yes ☐ No ☐ Not sure ☐

	No impact	**Low Impact**	**Moderate Impact**	**High Impact**	**Very High Impact**
21. How do you rate the effect of construction workers on project **cost**?					
22. How do you rate the effect of construction workers on project **completion**?					
23. How do you rate the effect of construction workers on project **quality**?					

D. MATERIAL

24. How is the availability of road construction material in Zambia (*please tick*)?

Very Poor ☐ Poor ☐ Average ☐ Good ☐ Excellent ☐ Not sure ☐

25. In your opinion, how would you rate the quality of locally available road construction materials (*please tick*)?

Very Poor ☐ Poor ☐ Average ☐ Good ☐ Excellent ☐ Not sure ☐

26. In your opinion, how would you rate the importation of road construction materials in Zambia (*please tick*)?

Very Poor ☐ Poor ☐ Average ☐ Good ☐ Excellent ☐ Not sure ☐

	No impact	**Low Impact**	**Moderate Impact**	**High Impact**	**Very High Impact**
27. How do you rate the effect of material on project **cost**?					
28. How do you rate the effect of material on project **completion**?					
29. How do you rate the effect of material on project **quality**?					

E. COST FACTORS

Apart from plant, equipment, construction workers and material there are other factors which affect unit costs in the Zambian road sector. Please indicate their impact on unit costs using the scale 1 to 5 where: 1= No impact, 2 = Low, 3 = moderate, 4 = high, 5 = Very high

S/No	Factor	Impact				
		1	2	3	4	5
1	**Corruption Perception Index** (CPI) - extent to which corruption is believed to exist					
2	**Project need -** Do road projects that are not budgeted have higher unit rates than budgeted ones, for example Formula 1 projects					
3	**Payments** regime of client. Do contractors factor potential delays in payment into pricing of contracts? What's the effect on unit rates?					
4	**Client Type –** whether government ministry, public institution (parastatal), private or foreign affect unit rate?					
5	**Contract financing -** Is the construction sector in Zambia a high risk sector with consequent impacts on the cost and ease of obtaining loans and performance bonds? How does this affect unit costs					
6	**Project planning –** how does the client's project planning such as insufficient budget allocations, appointment of supervision consultants after main contractor appointment, poor quality bidding documents, high contingency amount affect unit rates?					
7	**Project Management –** Client's capacity to supervise projects, level of variations, affect unit rates?					
8	**Procurement –** does the contractor selection method e.g open tendering, single sourcing affect unit rates?					
9	**Exchange rate** The contract conditions specify in which currency the payments will be made. Does the unit rate vary depending on the currency stated. Does the exchange rate risk on the purchase of imported materials or equipment affect unit rates?					
10	**Material shortages** – how do material shortages e.g. cement, fuel, bitumen affect unit rates?					
11	**Material Source** – how does the source of materials such as local or imported affect unit rates?					
12	How does **Contractor size** in terms of NCC grade category affect unit rates?					
13	**Contractor type -** such as foreign, local or joint ventures affect unit rates?					
14	Does **political interference** have an effect on unit rates?					
15	Does **Financial status or cashflow** of the contractor affect unit rates?					
16	**Overhead & Profit** – does the level of profit, overheads charged affect unit rates?					
17	If **Duration** is known, how does this affect unit rates?					
18	**Project scope –** new construction, rehabilitation, upgrading affect unit rates?					
19	**Location –** does remoteness of a project affect unit rates?					
20	**Hauling distance -** in transporting material and equipment affect unit rates?					
21	Do **Detour construction** on road projects affect unit rates?					
22	**Topography –** does the terrain affect unit rates?					
23	**Fuel –** does the price of fuel affect unit rates?					

30. From your experience, are there other cost factors not mentioned in the table above that you feel have a major impact on unit rates?
………
………
………

The End!
Thank you for your time.

Appendix B: NN source code generated

```
' Insert this code into your VB program to fire the C:\NeuroShell 2\EXAMPLES\RoadsCost_Factors network
' This code is designed to be simple and fast for porting to any machine.
' Therefore all code and weights are inline without looping or data storage
'  which might be harder to port between compilers.
Sub Fire_RoadsCost_Factors (inarray(), outarray())


' inarray(1) is Contractor_capacity
' inarray(2) is Project_Location
' inarray(3) is Financial_delays
' inarray(4) is Project_feasibility
' inarray(5) is escalation
' inarray(6) is Materials
' inarray(7) is Corruption_Perception_index
' inarray(8) is Political_Profile

if (inarray(1)<1) then inarray(1) = 1
if (inarray(1)>6) then inarray(1) = 6
inarray(1) = (inarray(1) - 1) / 5

if (inarray(2)<1) then inarray(2) = 1
if (inarray(2)>6) then inarray(2) = 6
inarray(2) = (inarray(2) - 1) / 5

if (inarray(3)<0) then inarray(3) = 0
if (inarray(3)>6) then inarray(3) = 6
inarray(3) = inarray(3) / 6

if (inarray(4)<3) then inarray(4) = 3
if (inarray(4)>4) then inarray(4) = 4
inarray(4) = (inarray(4) - 3)

if (inarray(5)<4) then inarray(5) = 4
if (inarray(5)>8) then inarray(5) = 8
inarray(5) = (inarray(5) - 4) / 4

if (inarray(6)<1) then inarray(6) = 1
if (inarray(6)>3) then inarray(6) = 3
inarray(6) = (inarray(6) - 1) / 2

if (inarray(7)<4) then inarray(7) = 4
if (inarray(7)>5) then inarray(7) = 5
inarray(7) = (inarray(7) - 4)

if (inarray(8)<3) then inarray(8) = 3
if (inarray(8)>5) then inarray(8) = 5
inarray(8) = (inarray(8) - 3) / 2

outarray(1) = (inarray(1) - 0.5879035) ^ 2
outarray(1) = outarray(1) + (inarray(2) - 0.3326241) ^ 2
outarray(1) = outarray(1) + (inarray(3) - 0.6259111) ^ 2
outarray(1) = outarray(1) + (inarray(4) - 0.0160955) ^ 2
outarray(1) = outarray(1) + (inarray(5) - 0.6330107) ^ 2
outarray(1) = outarray(1) + (inarray(6) - 0.3397955) ^ 2
outarray(1) = outarray(1) + (inarray(7) - 1.03615E-21) ^ 2
outarray(1) = outarray(1) + (inarray(8) - 0.1932815) ^ 2
outarray(2) = (inarray(1) - 0.5007468) ^ 2
outarray(2) = outarray(2) + (inarray(2) - 0.379489) ^ 2
outarray(2) = outarray(2) + (inarray(3) - 0.6537124) ^ 2
outarray(2) = outarray(2) + (inarray(4) - 0.1130998) ^ 2
outarray(2) = outarray(2) + (inarray(5) - 0.6903552) ^ 2
outarray(2) = outarray(2) + (inarray(6) - 0.3327692) ^ 2
outarray(2) = outarray(2) + (inarray(7) - -4.177255E-23) ^ 2
outarray(2) = outarray(2) + (inarray(8) - 0.261686) ^ 2
outarray(3) = (inarray(1) - 0.3832762) ^ 2
outarray(3) = outarray(3) + (inarray(2) - 0.4599568) ^ 2
outarray(3) = outarray(3) + (inarray(3) - 0.6953841) ^ 2
```

```
outarray(3) = outarray(3) + (inarray(4) - 0.2034733) ^ 2
outarray(3) = outarray(3) + (inarray(5) - 0.74957) ^ 2
outarray(3) = outarray(3) + (inarray(6) - 0.353333) ^ 2
outarray(3) = outarray(3) + (inarray(7) - 1.353729E-23) ^ 2
outarray(3) = outarray(3) + (inarray(8) - 0.3533376) ^ 2
outarray(4) = (inarray(1) - 0.2541946) ^ 2
outarray(4) = outarray(4) + (inarray(2) - 0.5769153) ^ 2
outarray(4) = outarray(4) + (inarray(3) - 0.7028536) ^ 2
outarray(4) = outarray(4) + (inarray(4) - 0.4040154) ^ 2
outarray(4) = outarray(4) + (inarray(5) - 0.780377) ^ 2
outarray(4) = outarray(4) + (inarray(6) - 0.3826127) ^ 2
outarray(4) = outarray(4) + (inarray(7) - 9.468667E-24) ^ 2
outarray(4) = outarray(4) + (inarray(8) - 0.4298017) ^ 2
outarray(5) = (inarray(1) - 0.141745) ^ 2
outarray(5) = outarray(5) + (inarray(2) - 0.7113859) ^ 2
outarray(5) = outarray(5) + (inarray(3) - 0.6857194) ^ 2
outarray(5) = outarray(5) + (inarray(4) - 0.6580003) ^ 2
outarray(5) = outarray(5) + (inarray(5) - 0.7244482) ^ 2
outarray(5) = outarray(5) + (inarray(6) - 0.398401) ^ 2
outarray(5) = outarray(5) + (inarray(7) - 1.429294E-23) ^ 2
outarray(5) = outarray(5) + (inarray(8) - 0.5118049) ^ 2
outarray(6) = (inarray(1) - 0.0946332) ^ 2
outarray(6) = outarray(6) + (inarray(2) - 0.8120039) ^ 2
outarray(6) = outarray(6) + (inarray(3) - 0.664867) ^ 2
outarray(6) = outarray(6) + (inarray(4) - 0.8226772) ^ 2
outarray(6) = outarray(6) + (inarray(5) - 0.6167297) ^ 2
outarray(6) = outarray(6) + (inarray(6) - 0.4551105) ^ 2
outarray(6) = outarray(6) + (inarray(7) - 1.839839E-23) ^ 2
outarray(6) = outarray(6) + (inarray(8) - 0.564807) ^ 2
outarray(7) = (inarray(1) - 7.215535E-02) ^ 2
outarray(7) = outarray(7) + (inarray(2) - 0.9066861) ^ 2
outarray(7) = outarray(7) + (inarray(3) - 0.6390648) ^ 2
outarray(7) = outarray(7) + (inarray(4) - 0.9524904) ^ 2
outarray(7) = outarray(7) + (inarray(5) - 0.4854837) ^ 2
outarray(7) = outarray(7) + (inarray(6) - 0.5343933) ^ 2
outarray(7) = outarray(7) + (inarray(7) - 9.534435E-24) ^ 2
outarray(7) = outarray(7) + (inarray(8) - 0.6001858) ^ 2
outarray(8) = (inarray(1) - 6.271633E-02) ^ 2
outarray(8) = outarray(8) + (inarray(2) - 0.9500438) ^ 2
outarray(8) = outarray(8) + (inarray(3) - 0.6284854) ^ 2
outarray(8) = outarray(8) + (inarray(4) - 0.9981665) ^ 2
outarray(8) = outarray(8) + (inarray(5) - 0.4268311) ^ 2
outarray(8) = outarray(8) + (inarray(6) - 0.573179) ^ 2
outarray(8) = outarray(8) + (inarray(7) - -1.089227E-22) ^ 2
outarray(8) = outarray(8) + (inarray(8) - 0.614438) ^ 2

End Sub
```

Appendix C: All in labour rate detailed calculations

All - in construction worker rates

Based upon Association of Building & Civil Engineering contractors (ABCEC) and National Union of Building, Engineering & General Workers (NUBEGW)

Joint Industrial Council Collective Agreement (2014 - 2015)

Description	Unit	Qty
Working hours per day	hrs	9
Working hours per week	hrs	45
Working hours per month	hrs	195
Working days per week	days	5
Public holidays per year	day	13
Annual leave	day	24
Sick leave	day	30
Compassionate leave	day	7
Inclement weather	hrs	40
Service benefit	hrs/ mth	30
Napsa	%/(basic hrs + annual le	5
WCF	%/(basic hrs + OT + lea	1.97
Medical	%/medical scheme	50
HIV training/first aid	%/probation period	0.5
Work suit (overalls)	K/no.	120
Gumboots	K/pair	75
Head gear	K/no.	35
Raincoat	K/no.	120
Uniform	K/no.	150
Reflector vest	K/no.	35
Safety shoes	K/pair	200
Tool allowance (car / pl)	%/basic rate	7.5
Housing allowance	%/basic rate	30
Funeral Benefit	K/event	2050
Max Advance	K/event	800
Incentive	K/day	0
Overtime rate	%/basic rate	1.5
Lunch allowance	K/day	11
transport	K/day	11
UTH medical scheme	k/mth	20
Typing costs per page	K/ page	3.5
Risk		0

Average working weeks in Zambia

No of weeks in a year	52
less annual leave (includes industry close down)	4.8
less public holidays	2.6
	44.6

(UK has 46.2 working weeks)

Annual and Public Holiday Pay is included in accordance with the ABCEC agreement.
Allowances are calculated on total weekly earnings

Description	Labourer	Equipment operator	Skilled labourer	Zambian Foreman	Driver	Security Guard/Watchman	
Rate	3.97	5.79	5.61	6.10	5.17	55.86	
Basic 45	178.65	260.55	252.45	274.5	232.65	223.44	(4 Shifts)
Holiday Pay (annual lea	19.23	28.04	27.17	29.54	25.04	24.05	
Sick leave	17.36	25.32	24.53	26.67	22.60	21.71	
Compassionate leave	5.61	8.18	7.92	8.62	7.30	7.01	
Public holidays	10.41	15.19	14.72	16.00	13.56	13.03	
Inclement weather	3.56	5.19	5.03	5.47	4.64	4.45	
Overtime	-	-	-	-	-	-	
Housing allowance	53.60	78.17	75.74	82.35	69.80	67.03	
Tool allowance	13.40	19.54	18.93	20.59	17.45		
Service benefits	32.04	46.74	45.28	49.24	41.73	40.08	
NAPSA	10.17	14.84	14.38	15.63	13.25	12.73	
WCF	4.79	6.99	6.77	7.37	6.24	5.67	
Protective clothing							
Work suit (overalls	2.69	2.69	2.69	2.69	-	-	
Gumboots	1.68	-	1.68	-	-	-	
Head gear	0.78	0.78	0.78	0.78	0.78	-	
Raincoat	2.69	2.69	2.69	2.69	2.69	2.69	
Uniform	-	-	-	-	3.36	3.36	
Reflector vest	0.78	0.78	0.78	0.78	0.78	0.78	
Shoes	-	4.48	-	4.48	4.48	4.48	
Funeral benefit	45.96	45.96	45.96	45.96	45.96	45.96	
Maximum advance	17.94	17.94	17.94	17.94	17.94	17.94	
Incentive	-	-	-	-	-	-	
Lunch	55.00	55.00	55.00	55.00	55.00	55.00	
Transport	66.00	66.00	66.00	66.00	66.00	66.00	
Medical / first aid	2.31	2.31	2.31	2.31	2.31	2.31	
Wagetkt	0.81	0.81	0.81	0.81	0.81	0.81	
Incidental costs	-	-	-	-	-	-	
Total	**545.47**	**708.19**	**689.57**	**735.43**	**654.39**	**618.53**	week
Rate/hr	12.12	15.74	15.32	16.34	14.54	13.75	

Appendix D: Copy of the Joint Industrial Council collective agreement (2014 - 2015)

<u>INDUSTRIAL & LABOUR RELATIONS ACT</u>

<u>SECTION 71 (1) (a) & (b)</u>

JOINT INDUSTRIAL COUNCIL COLLECTIVE AGREEMENT

(AS AMENDED 31st January 2014)

BETWEEN

THE ASSOCIATION OF BUILDING & CIVIL ENGINEERING CONTRACTORS (ABCEC)

AND THE

NATIONAL UNION OF BUILDING, ENGINEERING & GENERAL WORKERS

(NUBEGW)

FOR THE PERIOD

<u>EFFECTIVE 1st January 2014 TO 31st DECEMBER 2015</u>

1. **PERIOD AND SCOPE:**

1.1. This Agreement is entered into by and between the Association of Building and Civil Engineering Contractors (hereinafter called the "Association") and the National Union of Building Engineering and General Workers (hereinafter called the Union) whereas both parties agree that the document accurately reflects consensus reached during the course of negotiations and agree to abide by the terms and conditions of this Agreement.

1.2. The provisions of the Agreement shall apply to all members of the Joint Industrial Council and shall not apply to any support staff employed by the employer that are not members of the union.

1.3. This Agreement commences with effect from the 1st day of January 2014 and the contents herein shall have effect from the date aforesaid

1.4. The Parties hereto further agree that all benefits under the previous Agreement have been settled in full by the employer in compliance with the provisions therein.

2. **DEFINITIONS:**

2.1. "Building Industry" and/or "Industry" and or "Building and Allied trades" and or "Contractors involved in the Mining Industry" shall be deemed to cover the industry in which employers and employees are associated for the purpose of erecting, completing, air conditioning which requires structural adjustments or alterations, or additions, renovating, repairing, maintaining, or altering buildings or structures and/or the making and/or the manufacturing of articles for the use in erection, completion or alteration of buildings and structures, whether the work is performed, the materials are prepared, or the necessary articles are made on the sites of the buildings or structures or elsewhere, and shall include all work executed or carried out by persons therein who are engaged in the following activities or subdivisions therefore:"

2.1.1. "Air-conditioning which requires structural adjustments or alterations and additions and which include installations having for their purpose the delivery, extraction or conditioning of air for any purpose in any building or structure;"

2.1.2. "Asbestos/cement/and/or any substitute material which includes the fixing of roof covering whether of tiles, corrugated or flat sheeting, wall coverings, floor and wall tiling, pre-cast products, whether or not the fixing in the building or structure is done by the person making or preparing the article used;"

2.1.3. "Asphalting, which includes asphalting floors, roofs, water proofing foundations, basements or walls, laying method or other compositions and rubber flooring;"

2.1.4. "Bricklaying, which includes concreting and fixing of the concrete blocks, tiling of walls and floors, pointing, laying mosaic work, facing work in slate, in marble and in composition, drain laying, slating and roof tiling, asphalting, whether or not the fixing in the building or structure is done by the person making or preparing the article used;"

2.1.5. "Electrical installation, which includes electrical fitting and wiring and operations incidental thereto;"

2.1.6. "French polishing, which includes polishing with a brush or pad and spraying with any composition;"

2.1.7. "Joinery, which includes the manufacture of all articles of joinery, whether or not the fixing in the building or structure is done by the person making or preparing the articles used;"

2.1.8. "Lift installation, which includes the manufacture of lift cars or cages and the erection and/or maintenance of lifts;"

2.1.9. "Light making, lead and other metals, which includes the manufacture and/or fixing of lights, display signs and glazing relating thereto;"

2.1.10. "Masonry, which includes stone cutting and building (also the cutting of ornamental and monumental stone work); concreting, and the fixing or building of pre-cast or artificial stone or marble paving, mosaic work, pointing, wall and floor tiling, operating of stone working machinery and sharpening masons' tools, whether or not the fixing in the building or structure is done by the person making or preparing the article used;"

2.1.11. "Metal work, which includes the fixing of steel ceiling, metal windows, metal doors, builders' smith work, the fixing of drawn metal work, and sheet and extruded metal, whether or not the fixing in the building or structure is done by person making or preparing the article used;"

2.1.12. "Painting, which includes decorating paper hanging, glazing, (which includes bedding back, puttying and insertion of glass), distempering, lime or colour-washing, staining, graining and marbling and spraying and plastic texture work, stippler work, knotting and sign-writing;"

2.1.13. "Plastering, which includes modelling, granolithic and composition flooring, pre-cast or artificial stone work, wall and floor tiling, paving and mosaic work, making and fixing fibrous plaster and plaster board, asphalting, whether or not the fixing in the building or structure is done by the person making or preparing the article used;"

2.1.14. "Plumbing, which includes lead burning, gas fitting, sanitary and domestic engineering, drain laying caulking, ventilating, heating, hot and cold water fitting, including the fixing and water fitting of electric geysers, fire installation and the manufacture and fitting of all sheet metal work, whether or not the fixing in the building or structure is done by the person making or preparing the article used;"

2.1.15. "Shop, office and bank fittings, which include the manufacture and/or fixing of shop fronts, window enclosures, show cases, counters, screen and interior fittings and fixtures, whether manufactured in wood or metal;"

2.1.16. "Steel reinforcing, which includes the fixing of all classes of steel and other metal columns, girders, steel joints, or metal in any form which form part of a building structure provided that the total weight of such material shall not exceed two tons in any one building or structure;"

2.1.17. "Wood working, which includes carpentry, woodworking, machining, turning, carving, fixing of corrugated iron, sound and acoustic material, cork and asbestos insulation, wood lathing, composition ceiling and wall covering, plugging of walls, covering of woodwork with metal, block and other flooring, including wood and cork and sand papering of same, roof tiling, asphalting, whether or not the fixing in the building or structure is done by the person making or preparing the article used."

2.2. "Civil Engineering Industry" means without in any way limiting the ordinary meaning of the expression the industry in which employers and employees are associated for any or all of the following purposes;

2.2.1. "Construction of docks, harbour works, piers, quays, sea defences, wharves, aqueducts, bridges, cable ducts, viaducts, aerodromes, road bunkers, bins, cooling towers, silos, water towers, dams, irrigation works, pipelines, reservoirs, river woks, filter beds, sewerage works, sewers, railways, tunnels, caissons and mine shaft collars;"

2.2.2. "Civil engineering work in connection with thermal and hydro-electric schemes; cement grouting operations and pile driving; any other work of a similar nature, including excavations and foundation works involving problems of a civil engineering character."

2.3. ""Clerk" means an employee wholly or mainly engaged in writing and or typing and/or any other form of clerical or office work, including time-keeping."

2.4. "Continuous Period of Service" "means a period of service during which an employee has worked continuously for the same I employer without absenting himself save with lawful excuse or permission.

2.5. "Employee" means any person employed under a contract of service in the Industry.

2.6. ""Employer" means any person, or any firm, corporation, company, partnership, co-operative society or body of persons who or which employs any person to work under a contract of service, either oral or written, in the Building and Civil Engineering Industry."

2.7. ""Month" shall mean a continuous period of 195 normal working hours. Made up of a maximum of 45 hours per week Monday – Saturday, with a maximum of up to 9 hours per day."

2.8. "Joint Council" and/or "Council" means the Joint Council for the Building and Civil Engineering Industry.

2.9. ""Semi-skilled worker" means any person employed as a charge hand (Captain or workmen) or operative (person using or operating any of the power driven plant referred to under Operatives Class IV),"

2.10. "Skilled worker" means any person (other than a workman) employed in the Industry who is engaged in any one or more of the following trades and who holds the appropriate Trades Test Certificate issued by the council Bricklaying and/or plastering, carpentry, joinery, plumbing, sheet metal working, drain laying, electrical wiring, painting, glazing, driving and structural welding, bar bending and reinforcement fixing, concrete float, surface finishing, plant repair and maintenance, scaffolding, shutter fixing, structural steel work, timbering."

2.11. "Watchman" means a person engaged to watch over any property in or on any building, yard site or other place."

2.12. ""Workman" means any person engaged in any work in the Industry, which requires no particular training or skill."

2.13. "Working week" means six working days (which shall include Public Holidays for which the employee is in terms of this Agreement credited with one normal working day) in any seven consecutive days.

3. ALTERATIONS OR AMENDMENTS:

3.1. "The party requesting a review of the Agreement shall do so in writing and stipulate the proposed changes and indicate a proposed date, time and venue for the meeting."

3.2. Provided that always salaries and wages shall be reviewed on an annual basis.

4. DISPUTES:

4.1. "Any dispute regarding the interpretation application or administration of any provision of this Agreement may be handled as provided by the law on the settlement of Collective disputes or any dispute procedure, which may be agreed upon by the parties"

5. WAGES SALARIES AND ALLOWANCES:

5.1. The Parties agree that the minimum basic rate of wages paid to any person employed in the Industry shall be in accordance with this Agreement. Provided that nothing in this Agreement shall prevent the Union & individual employers from negotiating basic rates of pay and conditions of service in respect of specialised items of equipment not recorded in this Agreement.

5.2. The Parties have agreed that the basic rate of payment shall be per hour unless it is expressly stated otherwise. The parties have further agreed that the hourly rate of payment for each class of employee and each other such class that is paid a monthly basic salary shall be as set out in the first schedule of this Agreement and as amended from time to time when necessary.

6. CLASSIFICATION OF WORKERS:

6.1. WATCHMAN/SECURITY GUARD

6.1.1. "The Parties hereby agree that the hours of attendance of work by this class of employee shall be at the demand of the employer during hours outside the normal working hours of the employer,"

6.1.2. provided that a Watchman/Security Guard working more than four shifts in any calendar week consisting of seven consecutive days shall be paid overtime at the rate of ordinary full pay plus half of ordinary full pay plus half of ordinary full pay per shift for shifts worked.

6.1.3. "Provided also that in the case of a Watchman/Security Guard who is absent from work through illness and who produces a valid medical certificate, or, in the case of a Watchman/Security Guard who is absent from work with the permission of his employer, the shifts which such Watchman/Security Guard would normally have worked during the calendar week or calendar weeks when he was absent from work, shall be included in the time worked when calculating overtime."

6.1.4. All Shifts worked by a Watchman/Security Guard on a paid public holiday as defined in Section 5 of the Collective Agreement for the Industry shall be paid for those shifts worked on a paid public holiday. A shift in the case of a Watchman/Security Guard shall be of fourteen continuous hour's duration.

6.2. **SEMI SKILLED WORKERS:**

6.2.1. "The Parties have agreed that Semi Skilled workers shall include any person employed as a charge hand or operator person operating a mechanical device such as a concrete mixer, hoist, cook and lorry mate and such person shall be paid in accordance with the rate as set out in the first schedule for semi skilled workers."

6.2.2. The Parties have agreed that any person over the age of 21 years engaged in trade as defined by the term skilled worker and employed under supervision for the purpose of becoming skilled in that trade shall be classified a learner and paid in accordance with the relevant rate as set out in the first schedule.

6.2.3. Provided that no person shall be employed as a learner with one employer after completing twelve calendar month's continuous service.

6.3. **LICENSED DRIVER:**

6.3.1. The parties have agreed that consideration be given to the responsibility of the job when paying wages in excess of the minimum rate.

6.4. **SKILLED WORKER. CLASS III:**

6.4.1. The Parties have agreed that any person who has successfully taken a Grade I Trade Test approved by the Joint Council and who is in possession of either a Class III Trade Test Certificate issued by the Council or an Interim Certificate issued by a Technical College or a Trades Training Institute recognised by the Joint Council shall be classified a Skilled Worker and paid in accordance with this Agreement and as set out in the First Schedule.

6.4.2. "It has been further agreed that this class shall include a Painter/Glazier a Bricklayer/Plasterer a Sign-writer a Woodworking machinist a Carpenter and Joiner Cabinet maker an Electrical Wireman a Plumber, a Sheet-metal worker a Plant Mechanic and a Metal Fabricator/Boilermaker who has successfully taken a Grade I Trade Test as approved by the Council or such other Class III Trade Test as set out in this provision."

6.5. **SKILLED WORKER. CLASS II:**

6.5.1. "The Parties have agreed that any person who has successfully taken a Grade II Trade Test approved by the Joint Council and who is in possession of either a Class II Trade Test Certificate issued by the Council or a full Craft Certificate issued by a Technical College or a Trades Training Institute recognised by the Joint Council or an Interim Certificate holder with satisfactory practical experience shall be classified as a Class II worker and paid in accordance with such rate as set out in the first schedule. It has been further agreed by the parties that this class shall include the following a Painter/Glazier a Bricklayer/Plasterer a Sign-writer a Woodworking machinist a Plumber, a Sheet-metal worker a Carpenter and Joiner Cabinet maker an Electrical Wireman a Plant Mechanic and a Metal Fabricator/Boilermaker who has successfully taken a Grade II Trade Test as approved by the Council or such other Class II Trade Test as set out in this provision."

6.6. SKILLED WORKER CLASS I:

6.6.1. "The Parties have agreed that any person who has successfully taken a Grade III Trade Test approved by the Joint Council and who is in possession of either a Class I Trade Test Certificate issued by the Council of a full Craft Certificate issued by the Council or a full Craft Certificate with satisfactory practical experience shall be classified as a class I Skilled Worker and shall include a Painter/Glazier a Bricklayer/Plasterer a Sign-writer a Woodworking machinist a Plumber, a Sheet-metal worker a Carpenter and Joiner a Cabinet maker an Electrical Wireman a Plant Mechanic and Metal Fabricator/Boilermaker."

6.7. SECURITY OFFICER/POLICEMAN:

6.7.1. The parties have agreed that this includes any person who has undergone formal training in police work and such person shall be paid a wage as set out in the first Schedule.

6.8. OPERATIVES CLASS IV:

6.8.1. The Parties have agreed that this shall include any semi-skilled workman using or operating any or all of the such power driven plant equipment that shall include Compressors Crushers Dumpers up to and including 1m3 capacity Mixers Power-driven tools Rollers including up to and including 2T and Winches other than piling winches.

6.9. OPERATIVES CLASS III:

6.9.1. The Parties have agreed that this shall include any semi-skilled workman using or operating any or all of such power driven plant equipment that shall include Cranes Derricks Dumpers over lm3. Capacity Lorries Mechanical Spreaders Rollers over 2T small tractors and attachment up to approx 38kW piling Winches and Excavators of up to approx 38kW.

6.10. OPERATIVES CLASS II:

6.10.1. The Parties have agreed that this class shall any person who operates Dumpers (Euclid or similar) Earthmoving tractors & attachments Graders Excavators and Loading Shovels in excess of 38kW and up to 1m3. Capacity Trenchers.

6.11. OPERATIVES CLASS I:

6.11.1. "The Parties have agreed that this class shall include any person employed to operate Excavators and Loaders Shovels in excess of 1m3 capacity and an operator of major mechanical plant designated by his employer and who when a Trade Test and Trade Test Certificate are approved by the Joint Council, has passed such test and is in possession of the appropriate Trade Test Certificate."

6.12. OPERATIVES CLASS II GRADE A:

6.12.1. "The Parties have agreed that this class shall include any person who operates Shovels more than 3.2m, Cranes more than 20 tonne and Loaders more than 4m."

6.13. OPERATIVES CLASS II GRADE B

6.13.1. The Parties have agreed that this class shall include any person operating Bulldozers/Pushers of more than 110kW Scrapers of more than 18m. or 30T Dumpers more than 18m. or 30T Graders Loaders of more than 1.8m Cranes of more than 10T Blast-hole drills of more than 100mm. Diameter Shovels of less than 3.6m Water-cart of more than 30T and Compactors of more than 20T.

6.14. OPERATIVES CLASS II GRADE C:

6.14.1. "The Parties have agreed that this Class shall include any person operating a Bulldozer of less than 110kW Scrapers of less than 18m or 30T Dumpers of less than 18m. or 30T Loaders of more than 1.8M Cranes of more than 5T Water-carts of more than 9,000ltr Wagon drills of 10mm. Diameter or less License Blaster Drivers (general purpose vehicle) Pump-man (Static installation) Learner Blaster Artisan helper Tally checker-spotters Greasers Banks-man Workman Provided that there shall be no difference in the wages of open pit workers working on the surface or in the open pit."

6.15. UNDERGROUND WORKERS:

6.15.1. "The Parties have agreed that that this class of employees shall include the Section Boss, Ganger, Assistant Ganger, Artisan, Grouting Operator, Crew Boss I, Crew Boss II, Loader Driver, Loco Driver, Hoist Driver, Machine-man, Spanner-man, Artisan Loading hand, Banks-man, Lashers, Stage-Hand, Grouting-helper, Artisan helper, Change-house man, Bank helper, Batching plant helper, Sanitation, Messenger, Cleaner."

6.16. SUPPORT STAFF ON MONTHLY SALARY:

6.16.1. "The Parties to this Agreement have further agreed that the following staff shall be on a monthly salary as set out in the Second Schedule hereto a book-keeper with the ability to take book up to trial balance, Secretarial-Shorthand/Typist with the ability of 80 words per minute typing, Audio typist with the ability of 35 Words per minute typing, Copy Typist with the ability of 34 words per minute typing, Accounts Clerk with the ability to meet the requirements of the job, Ledger Clerk with the ability to meet the requirements of the job."

6.16.2. The Parties have further agreed that there shall be different classes of clerical staff and the salary for each such shall be as set out in the Second Schedule.

6.16.3. "The Parties have further agreed that Class I General Clerks shall include Site Clerks, Timekeepers, Stores Clerks, Sales Clerks, and Wages Clerks (with the ability to meet the requirements of the job)."

6.16.4. The Parties have further agreed that Class II General Clerks shall include a Receptionist Telephone operator and Filing Clerks with the ability to meet the requirements of the job.

6.16.5. "The Parties have further agreed that the clinical staff as set out in this provision shall be paid a monthly salary as set out in the second schedule and shall include Nurses, Clinical Assistants, Zambia Enrolled Nurses (ZEN), Registered Nurses."

6.16.6. Provided that always no person covered by this Agreement already receiving a wage or salary in excess of such wage or salary laid down in this amendment shall suffer any reduction of wage salary or conditions enjoyed by such person prior to the signing of this amendment.

7. SHIFT WORK:

7.1. Where work is carried out at night by separate gang or gangs of men from those working during normal day time hours men so working shall be paid at the rate of ordinary full pay plus a shift differential calculated on a rate of 15 Percent of such employees basic hourly rate of pay.

7.2. Provided that always the shift differential shall be deemed to be conditional payment and shall not be enhanced when calculating overtime payments. Normal overtime provisions shall apply for hours worked in excess of forty-five (45) per week.

7.3. The Parties to this Agreement further reaffirm that the long standing custom in the industry that irregular hours have on occasion to be worked and therefore the shift differential shall be paid only when the gang or gangs in question have worked these irregular hours for a continuous period of six months provided that always no retrospective payments shall be made.

8. OVERTIME AND HOURS OF WORK:

8.1. The normal hours of work for a working week shall not exceed forty-five (45) hours provided that always an employee shall not be required to work continuously for more than five and half-hours without a break of not less than thirty minutes. The time of such break shall be at the discretion and fixed by the employer provided that alterations in the time set for such break do not take place unless thirty days notice has been given to the employees. The Employer shall notify the employees of the time of such break by means of a notice displayed in a conspicuous place at the place of work

8.2. "Where an employee has worked for more than forty-five hours in any working week the hours worked in excess of forty-five shall be paid at the rate of ordinary full pay for that time plus half of ordinary full pay for that time provided that in the case of an employee who is absent from work through illness and who produces a valid medical certificate or in the case of an employee who is absent from work with the permission of his employer the hours which such employee would normally have worked during the shift or shifts when he was absent from work shall be included in the time worked when calculating overtime, provided that further when the normal working week as fixed by the management as provided in the above paragraph shall apply to all hours worked in excess of such normal working week."

8.3. Where the hours worked by the employee in any one day extend past midnight into the following day then the hours worked past midnight shall be paid at the basic rate of ordinary full pay for that time plus ordinary full pay for that time.

8.4. All hours worked on a Sunday or on Christmas or New Year's Days shall be paid at the basic rate of ordinary full pay for that time plus ordinary full pay for that time in addition to the pay due to the employee in terms of the second schedule of this Agreement.

8.5. Provided that always the provisions of these paragraphs shall not apply in the case of a watchman. The hours to be paid as over-time shall be determined at the conclusion of each working week.

9. PUBLIC HOLIDAYS:

9.1. The Parties have further agreed that paid Public Holidays will be granted as Gazetted and presently includes such public holidays as set out in the Fourth Schedule of this Agreement. Payment in respect of the said holidays as set out in the Fourth Schedule shall be made at the current basic rate of the employee concerned on condition that the employee is available for work for his employer on the next preceding working day and on the next following working day.

9.2. The following is a list of Paid Public Holidays:

9.2.1. New Years Day
9.2.2. International Women's Day
9.2.3. Youth day
9.2.4. Good Friday
9.2.5. Holy Saturday
9.2.6. Easter Monday
9.2.7. Labour Day
9.2.8. Africa Freedom Day
9.2.9. Heroes Day
9.2.10. Unity Day
9.2.11. Farmers Day
9.2.12. Independence Day
9.2.13. Christmas Day

10. ANNUAL CLOSE DOWN:

10.1. The Parties have agreed that there shall be an Annual Close Down period of all work places that are governed by this Agreement and the period of such close down shall be for 14 (Fourteen) consecutive days and as set out by the Joint Industrial Council in **Clause 10.4**

10.2. Any employee, (**other** than a Watchman/Security guard or employees working on operations involving continuous production within the mining sector) working during the Annual Close down shall be paid at the rate of ordinary full basic rate of pay for the time worked plus an additional ordinary full basic rate of pay for that time so worked during the Annual Close Down period.

10.3. The worker shall be granted as early as possible thereafter a period of leave equal to the period which he has so worked.

10.4. Closedown Dates

10.4.1. Saturday 20th December 2014 to Sunday 4th January 2015.
10.4.2. Saturday 19th December 2015 to Sunday 3rd January 2016

11. ANNUAL LEAVE:

11.1. Accumulation: Every employee shall be entitled to two days at paid leave for each full month worked calculated on the basic rate of pay. Provided that any employee may take leave proportionate to the amount of leave accumulated during the first six months of service. And further provided that always the employee shall take leave during the Annual Close Down period as provided in Clause 11 above.

11.2. Scheduling and Granting of Leave: The scheduling and granting of annual leave that falls out of the Annual Closedown period is at management's discretion. As far as possible and subject to operational requirement an employee's request for annual leave is to be scheduled at a time convenient to the employer. The employer shall have the right to give reasonable consideration to the necessity and interests of the business of the employer in agreeing to the dates when such leave may be taken

11.3. Commutation of Leave There shall be no commutation of leave except upon termination of service.

11.4. Employment While on Leave: No employee shall take up other employment while on leave.

11.5. Notice of Termination While On Leave: An employee may give notice of termination while on Leave but services shall be terminated on the last day of the prescribed notice period of Thirty (30) days.

12. SICK LEAVE:

12.1. "Sick Leave entitlement is calculated over a thirty six (36) month cycle, the first cycle commencing with the first day of employment. A maximum of ninety (90) days paid sick leave can be taken during such cycle subject to the provisions of this section, only when supported by a bona fide medical certificate."

12.2. Thereafter such Leave shall be on half pay provided that if an employee continues to be on sick leave at half pay for more than ninety (90) days the employer may discharge the employee on recommendation of a registered medical practitioner whereupon his entitlement to sick leave shall cease.

13. MEDICAL RETIREMENT:

13.1. "If in management's opinion an employee's use of sick leave is excessive the employer retains the right to obtain a medical opinion on the employee's ability to fulfil his employment obligations and or to initiate ill health retirement by seeking a recommendation by a Medical Board set up by the Minister of Health, regardless of the number of days left in the employees sick leave cycle. An employee proceeding on medical retirement will be entitled to benefits as determined by the Joint Council."

14. PAID MATERNITY LEAVE:

14.1. All female employees who have completed twenty-four (24) months of continuous service shall be entitled to ninety(90)days paid maternity leave exclusive of any other leave due to such female employee. In cases of illness arising out of pregnancy that results in a female employee being temporarily incapable of performing her official duties such employee shall be entitled to sick leave in accordance with the provisions of Clause 14 of this agreement.

15. COMPASSIONATE LEAVE:

15.1. "In the event of the death of a member of an employee's biologically related and registered family member namely mother, father, sister, brother, son, daughter, or spouse up to a total (maximum) of seven (7) paid working days compassionate leave shall be granted in any calendar year."

15.2. Compassionate leave shall not be granted until the employee so affected has submitted documentary proof of the occasion justifying the award of such leave to the employer. Provided that always the granting of such leave as aforesaid shall not affect such terminal benefits/gratuity and leave pay that are or may be due to an employee.

16. DECEASED EMPLOYEES BENEFITS:

16.1. "The Employers party to this agreement have agreed that a standard coffin or the cost of such coffin shall be provided on the death of an employee, registered spouse or child under the age of **18** years and such child is unemployed"

16.1.1. "On the death of an employee, the employer will give assistance in providing transport to and from the cemetery. In the event that the employer is unable to provide such transport a sum of **K800.00** will be granted by the employer."

16.1.2. "On the death of an employee's immediate family i.e. registered spouse or child under the age of 18 years and such child is unemployed **K600.00** shall be granted for either the wife or any child."

16.2. "The employer shall further grant the sum of **K900.00** to the family of the deceased employee, **K650.00** on the death of the registered spouse of an employee and **K600.00** on the death of the registered child of an employee who is under the age of Eighteen (18) years of age and unemployed."

16.3. "On the death of a parent or such other relative close to the employee the employer will make a compassionate loan of up to **K800.00** to assist the employee. Provided that always the employee shall provide documentary proof of the event. See also **Clause 15- Compassionate Leave.**"

17. REPATRIATION BENEFITS:

17.1. "In the event the service of any employee is terminated by reason of redundancy, the attainment of the retirement age, discharge for medical reasons or by the death of the employee, such employee or his family, as the case may be shall be entitled to be transported by the employer to the employee's place of recruitment or be paid a repatriation allowance by the employer equal to the current cost of travelling by public transport and the most direct route to the employee's place of recruitment"

17.1.1. Such repatriation shall take place only upon the specific request of the employee or his family as the case may be and provided always that such repatriation shall be within three months of the termination of such employment with in the provisions of this clause.

18. OTHER ALLOWANCES:

18.1. **DAILY TRANSPORT ALLOWANCE:** The Company shall provide the employee with transport for daily travel to and from the vicinity of the employee's residence to his/her place of work or in lieu of such transport the Company shall pay to the employee the sum of **K11.00per Shift or Day.**

18.2. **MEDICAL SCHEME:** The parties have agreed that the employer shall contribute fifty percent on a monthly basis towards the Government Medical Scheme to include employee, spouse and up to five registered children under the age of eighteen years and not working.

18.3. **HOUSING ALLOWANCE:** The Parties have agreed that the employer shall pay the employee a housing allowance of Thirty percent (30%) of the basic salary of such employees' salary as set out in the first and second schedule of this Agreement.

18.4. **TOOL ALLOWANCE:** Any skilled worker who is engaged in an occupation requiring the use of hand tools shall be paid in consideration for using his own hand tools an allowance of **7.5 per cent** of his basic monthly wage earned over the month. Provided that always the allowance shall be paid only when the skilled worker is in possession of such set of those tools as prescribed by the Joint Council and described in the third schedule hereto as being appropriate to his occupation and when the said set is found to be complete and in good condition on inspection by his employer.

18.5. **LUNCH ALLOWANCE:** The Company shall provide the employee with a lunch allowance of **K11.00 per shift or day.**

19. REGULATIONS GOVERNING THE DEPLOYMENT OF EMPLOYEES AWAY FROM STATION:

19.1. The welfare of the employee shall be governed by the following provisions when such employee is deployed to work out of station.

19.1.1. "Where work is to be done away from an employee's normal place of work, the employer shall provide for such employee Company transport, in the event that such transport is not available the employee sent to do such work shall be provided with adequate finances by the employer to pay full transport costs by taxi or bus to and from such other place of work."

19.1.2. "In the event of the employee not returning to his usual domicile the same day whilst in transit travelling between jobs then in addition to transport being provided the employer will pay to the employee a night allowance of One Hundred and **K110.00** for each night spent whilst travelling in transit."

19.1.3. "When such employee is required by the employer to take on a job, which is away from his usual domicile, adequate temporary waterproof hygienic accommodation shall be provided for by the employer. In addition the employee shall be paid **K150.00** per month or proportion thereof for the days of the month while living on the job."

19.1.4. "If for any reason the employer is not able to provide accommodation in accordance with section (19.1.3) above, then the employer shall instead pay the employee **K130.00** per night for each night spent away from his normal domicile."

19.1.5. "For the purposes of section((19.1.3) and (19.1.4)) above 'days' and 'nights' shall include Saturdays, Sundays and Public Holidays, regardless of whether the employee actually works these days"

19.1.6. "In addition to section (19.1.3) above and when applicable any employee required by his employer to take on a job which is away from his usual domicile, then such an employee shall also receive an initial one off settling in allowance of **K180.00**."

20. **PROTECTIVE CLOTHING AND MAINTENANCE OF SAFETY :**

20.1. Every employee who is required to work in direct contact with mass concrete or other similar work likely to be injurious to his feet shall be supplied by his employer with gumboots and gloves.

20.2. "Every employee who is required to load or unload any vehicle during the rainy season, or who is otherwise obliged to work in the rain without shelter, shall be supplied by his employer with a raincoat."

20.3. Every employee shall be provided with suitable protective clothing by his employer when the nature of his work so requires and in accordance with the Factories Act.

20.4. Permanent staff will be supplied twice per year with overalls or dustcoats and once per year with safety boots or shoes. These will be provided free of charge but will remain the property of the employer and be handed back to the employer on receipt of new protective clothing or on termination of employment.

20.5. The employer will keep a stock of protective headgear for use by its employees on a daily draw basis.

20.6. In the event of loss or damage of protective clothing so provided by the employer due to the negligence of an employee the employee shall be required to pay for the replacement or repair of such clothing or any other safety item provided by employer to the employee.

21. **LAY OFF:**

21.1. "DUE TO BAD WEATHER An employee reporting for work at the regular reporting time and being told by his employer that it is impossible to work because of the inclement weather, shall be entitled to four hours' pay for that day. If an employee is stopped by his employer from working because of bad weather, then the employee shall be entitled to be paid for the hours worked on that day and one additional hours' pay for that day, provided that the total is not less than four hours."

21.2. DUE TO LACK OF MATERIAL An employee reporting for work at the regular reporting time without being notified to do otherwise shall be entitled to a normal working day's pay. Lay-Offs due to lack of supply of material or other contractual delay deemed not to be the responsibility of the employer shall not extend beyond forty-five working days. On the forty-sixth day the employee shall be given work or made redundant and redundancy clause applied.

21.3. NOTICE of such lay-off shall be given to the employee on the day preceding the lay-off either by means of a notice displayed on the site or verbally by the employer or by a person nominated by the employer.

22. **ACCIDENTS:**

22.1. "The employee shall refrain from any action/practice, which might endanger his safety and the safety of others at working places. Moreover the employee shall comply with and make use of such safety devices that may be provided by the employer at places of work."

22.2. Every employer shall undertake to provide a safe working environment for the employee. The parties to this agreement have a joint responsibility for the maintenance of safety standards

22.3. "All accidents occurring at the employees working place involving injury, whether minor or serious must be reported immediately by the employee to the Union representative and to the employee's immediate supervisor who shall report to Management which in turn shall report to the Workmen's Compensation Commission"

23. MEDICAL REGULATIONS:

23.1. "Employees shall submit to any medical examination, which the Company may require at any time."

23.2. If a male' employee absents himself for even one day on account of sickness he will be regarded as being absent unless he has obtained a certificate from a doctor or medical authority recognised by the Government to issue such certificate.

23.3. A Female Employee shall be entitled to ONE DAY absence per month without having to produce a medical certificate.

24. REDUNDANCY:

24.1. The service of an employee shall be deemed to have been terminated by reason of redundancy if the termination is wholly or in part due to

24.2. The employer ceasing or intending to cease to carry on the business by virtue of which the employee was engaged or

24.3. The business ceasing or reducing the requirement for the employee to carry out work of a particular kind in the place where the employee was engaged and the business remains a viable going concern.

24.4. PREVENTION OF REDUNDANCY:

24.4.1. "The Management will inform the union at least three (3) months prior to initiating any redundancies, in order that the parties may consult on ways of preventing such redundancies through the consideration of the following options:"

24.4.2. The cessation of recruitment of new employees within affected grades

24.4.3. Transfer of such potentially redundant employee or employees to other positions within the work place for which such potentially redundant employee is qualified

24.4.4. Reduction of overtime as much as practically possible and practical .

24.4.5. Where possible and practical the employer may provide appropriate onsite training that could qualify such potentially redundant employee for an alternative position.

24.5. RULES OF APPLICATION:

24.5.1. When the consultation between the employer and Union fail to result in any avoidance of redundancy the following will apply

24.5.2. The employer shall submit a list of names and positions of such employees and the dates on which redundancy notices shall be issued to affected employees;

24.5.3. "The principal of first in last out shall apply subject to such other criteria such as skill, ability, performance and record shall be taken into account"

24.5.4. A redundant employee shall retain recall rights for up to six (6) months from the date of being made redundant which will entitle the employee priority consideration should any vacancies occur for which the employee is qualified and suitable.

24.5.5. It shall be the responsibility of the redundant employee to keep the company informed of the employee's current postal address for the purpose of receiving a recall notice. In the event that there is no response from such an employee within twenty (20) days of notice being sent to an employee last so registered address the employer is not obliged to delay recruitment for the position.

24.6. REDUNDANCY BENEFITS:

24.6.1. As of 1st January 2001 any confirmed employee made redundant will receive one month's notice or pay in lieu of plus a redundancy benefit of thirty two and a half (32.5) hours at the basic rate of payment at time of redundancy for every completed month of service.

24.6.2. "The parties have further agreed that such amounts accrued by the employee prior to the first day of January, 2001 have been settled in full by the employer under previous agreements and in compliance with the provisions therein under the Terminal/Service Benefit/Gratuity Clause."

25. SERVICE BENEFITS:

25.1. The Parties have agreed, that the employer shall pay the employee thirty (30) hours pay for each completed month of service at the hourly rate as set out in the schedule hereinafter as service benefits provided that always such amount shall become payable to the employee by or soon after the 14th January of every year. The Parties have further agreed that such amount shall accrue to the employee for the current period commencing from the 1st day of January 2014 to the 31st December 2015"

25.2. The monthly pay slip shall indicate the amount due for the current month and the amount accrued during the period

26. RETIREMENT BENEFITS:

26.1. An employee who has attained the statutory retirement age of fifty-five (55) years shall be notified in writing six (6) months prior to the date of retirement. The retirement benefits due to the employee shall be such as are due to the employee from such employer-employee contributions to NAPSA. It shall be the sole responsibility of the employee to recover such contributions from NAPSA that are due to such employee.

26.2. "Retirement benefits shall be such benefits as provided under the NAPSA Scheme the employer contributing fifty per cent of such amount of contribution, as the employee is to contribute to the aforementioned scheme."

26.3. "An employee who has served with the employer for not less than ten (10) years shall be entitled to three (3) months basic pay for each year served. In the event that the employee has not served for a period exceeding ten (10) years, then no retirement benefits shall accrue other than those included herein as gratuity payments and as provided for under NAPSA. The parties have further agreed that such amount shall accrue to the employee with effect from 1st January 2001 and that all benefits under the previous Agreement have been settled in full by the employer in compliance with the provisions therein."

27. TERMINATION OF EMPLOYMENT:

27.1. "Should the employer terminate the employment of an employee for reasons other than redundancy as defined in this Agreement then the employer shall state those reasons, such as misconduct or incompetence."

27.2. "The termination shall be subject to the relevant provisions of the Law and in addition, the employer shall make known his intention to the Union before implementing any decision to terminate the services of an employee."

27.3. Nothing in the foregoing shall abrogate the right of an employer to summarily dismiss an employee on grounds recognised by law as justifying instant termination of a contract of employment.

27.4. "Notwithstanding the foregoing, the Notice of termination of a confirmed employee shall be thirty (30) calendar days by either party or thirty (30) days pay in lieu of such notice."

28. **CERTIFICATE OF SERVICE:**

28.1. On the termination of service every employee shall be given a certificate setting out the details of his service and employment as follows:

28.1.1. Name of employer.
28.1.2. Name of Employee
28.1.3. National Registration Card Number.
28.1.4. Year of Birth.
28.1.5. Trade of employee.
28.1.6. Grade in trade of employee.
28.1.7. Date of engagement.
28.1.8. Date of termination of service.
28.1.9. Rate of pay on engagement of service.
28.1.10. Rate of pay on termination of service.
28.1.11. The employer's account number with the NAPSA.
28.1.12. The employee's NAPSA Social Security Number.
28.1.13. A statement showing the amount of statutory and supplementary contributions paid by the employer to NAPSA in respect of the employee.
28.1.14. Signature of the employer.

29. **OCCUPATIONAL HEALTH AND SAFETY GENERAL PROVISIONS**

29.1. There shall be no lifting of heavy loads that can cause injury to workers.

29.2. "The Employer shall provide adequate supply of clean drinking water, washing facilities, enough toilets and for the employees.

29.3. In places of permanent work adequate lockers for storage of personal effects

29.4. "In every factory/workshop, there shall be an equipped First Aid Box and at least two (2) employees trained as First Aiders."

30. **EDUCATION AND TRAINING**

30.1. "The Employer shall provide adequate education and training on the Occupational, Health and Safety issues, HIV and AIDS inclusive"

30.2. All new and in-experienced workers must be given full information on the dangers and precaution to take when working with machines.

31. "**OCCUPATIONAL, HEALTH AND SAFETY STRUCTURES**"

31.1. The Company to formulate a Safety Policy.

31.2. There shall be established a Health and Safety Committees at the undertaking.

32. **PERIOD OF AGREEMENT**

32.1. "This agreement shall become effective from 1st January 2014 such date as approved by the Minister of Labour and Social Security and shall remain in force for a period of One year up until the 31st December, 2015 unless before the said 31st December, 2015 it is:

32.1.1. Amended at a properly constituted meeting of the Joint Council for the Building and Civil Engineering Industry called in accordance with the provisions of the constitution of the Council.

32.1.2. Terminated or replaced at a properly constituted meeting of the Building and Civil Engineering Industry called in accordance with the provisions of the Constitution of the Council.

FIRST SCHEDULE **Basic Rates of Pay** **Effective 1 January 2014**

JOB DESCRIPTIONS	**Re Based Kwacha**	
BuildingTrades	**unit**	**K.Rate**
Security Guard/Watchman	Shift	55.86
Workmen	HR	3.93
Semi-Skilled Worker/Learner	HR	3.97
Licensed Driver	HR	5.12
Skilled Worker-Class III–Painter/Glazier, Brick-layer/Plaster, Sign writer, Woodworking mach., Plumber, Sheet metal worker, Carpenter, Jointer, Electrical Wireman, Plant Mechanic, Metal fabricator/Boiler Maker, Cabinet Maker	HR	4.81
SkilledWorker-ClassII–Painter/Glazier,Bricklayer/Plasterer,Signwriter, Woodworkingmach,Plumber,Sheetmetal worker	HR	5.12
Skilled Worker-Class II–Carpenter/Joiner, Electrical Wireman, Plant Mechanic, Metal Fabricator/Boiler Maker, Cabinet Maker.	HR	5.17
Skilled Worker-Class I-Painter/Glazier	HR	5.48
Skilled Worker-Class I–Bricklayer/Plasterer, Sign writer, Wood working machinist.	HR	5.53
Skilled Worker-Class I–Plumber, Sheet metal worker, Carpenter/Jointer, Electrical Wireman, Plant Mechanic, Metal Fabricator/Boiler Maker, Cabinet Maker	HR	5.61
Security Officer/Policeman	HR	3.96
Welder/fitter(1Yearexp)	HR	4.81
Welder/fitter(2yearexp)	HR	5.17
SteelFixer I	HR	3.96
Steel-Fixer II	HR	4.81
Operative Class IV	HR	4.23
Operative Class III	HR	5.12
Operative Class II	HR	5.39
Operative Class I	HR	6.02
Open Pit Section Boss	HR	6.10
Open Pit Operative Class II Grade A	HR	5.79
Open Pit Operative Class II Grade B	HR	5.30
Open Pit Operative Class II Grade C	HR	4.77
Licensed Blaster/Driver Gen. Purpose vehicle, Pump man–Static Install	HR	5.17
Learner Blaster, Artisan Helper/ Tally Checker–Spotter, Greaser, Banks man	HR	3.96
Workman	HR	3.97

JOB DESCRIPTIONS		
Underground Workers	**unit**	**K.Rate**
Section Leader	HR	6.24
Ganger	HR	6.16
Assistant Ganger	HR	5.79
Artisan	HR	5.67
Grouting Operator/ Crew Boss I	HR	5.61
Crew Boss II	HR	5.67
Loader Driver/Loco Driver	HR	5.26
Hoist Driver	HR	5.67
Machine-man	HR	5.26
Spanner Man	HR	4.86
Artisan Loading Hand/ Banks man	HR	4.90
Lasher, Stage Hand, Grouting Helper, Artisan Helper, Change house Man, Bank Helper, Batching Plant Helper, Sanitation, Messenger, Cleaner	HR	4.14
CLERICALSTAFF-Wages Paid Monthly	unit	
Book-keeper	Mth	1 363.00
Secretarial-Shorthand Typist	Mth	1 230.00
Audio Typist	Mth	1 119.00
Copy Typist	Mth	1 098.00
Accounts Clerk/Ledger Clerk	Mth	1 141.00
General Clerks I	Mth	1 009.00
General Clerks II	Mth	949.00
MEDICALSTAFF	unit	
Clinical Assistant	Mth	1 268.00
Zambia Enrolled Nurse (ZEN)	Mth	1 429.00
Registered Nurse	Mth	1 569.00

SECOND SCHEDULE

The Following is the prescribed set of tools herein before referred to. All artisans are expected to have an appropriate tools box.

1. Brick-Layer/Plasterer:

1 x Cold Chisel
1 x Hammer (2lb)
1 x Spirit Level (1m)
1 x Building Line
1 x Trowel
1 x Pointing Trowel
1 x Wood Float
1 x Brick Layers Square (Flat & Phillips)
1 x Tape measure (3m)
1x Spirit Level (30cm)

2. Carpenter/Joiner

1 x Ratchet Brace
1 x Wood chisel set (6mm – 25mm)
1 x Claw Hammer
1 x Jack Plane (300mm minimum)
1 x Hand Saw
1 x Tenon Square
1 x Screw Driver (30cm & 15cm)
1 x Tape Measure (3m)

3. Plant Mechanic

1 x Set of Spanners (ring/flat comb. 6-22mm)
1 x Shifting Spanner (30cm)
1 x Pipe Wrench (45cm)
1 x Hammer (ball)
1 x Hammer (4lb)
1 x Cold Chisel (25cm)
1 x Pliers
1 x Set of Screw Drivers (Flat & Phillips)
1 x Screw Driver

4. Plumbers

1 x Pipe wrench (30 & 45cm)
1 x Shifting Spanner (30cm)
1 x Cold Chisel (25cm)
1 x Brick Hammer
1 x Pliers
1 x File (steel)
1 x Hacksaw
1 x Rasp file
1 x Tape (3m)

5. Electrician

1 x Tape Measure (3m)
1 x Chasing Hammer
1 x Pliers (insulated)
1 x Hacksaw
1 x Electricians Tester
1 x Shifting Spanner (20cm)
1 x Side Cutter (insulated)
1 x Set Screw Driver (Flat & Phillips)

CONTRACT OF SERVICE:

1. **Probation:** The probationary period shall be three (3) calendar months. During which period the terms and conditions of service of the employee shall be as spelt out in the letter of offer of employment. During the probation period, employment may be terminated by either party giving twenty-four (24) hours notice, or one days pay in lieu thereof.
2. **Confirmed Employees:** Once an employee has satisfactorily completed the probationary period, the employee shall be confirmed in the position. The terms and conditions of service of the confirmed employee shall be governed by the letter of appointment, the provisions of this Collective Agreement and any other relevant employment legislation.
3. **Termination of Employment**: Notice of termination of employment of a confirmed employee shall be thirty (30) calendar days by either party, or thirty (30) days pay in lieu thereof. Termination of an employee's service by the employer shall be in accordance with the such procedures as are agreed by the parties in respect to discipline, incapacity or redundancy

DISCIPLINARY CODE:

The parties have agreed that the offences shall be divided into four categories of offences. In the interest of all parties extenuating or mitigating factors will always be taken into account. It has been further agreed that an individual's entire employment record shall be taken into account.

CATEGORY I:

This category shall include such offences as poor time keeping, failure to wear protective clothing, poor work performance and such similar offences. The parties have agreed that this category of offence shall result in a written warning from the employer to the employee which letter shall become a part of the employees' record of employment.

CATEGORY II:

This category shall include such offences as sleeping on duty, failure to follow standing instructions, violations of safety rules and such similar offences. The parties have further agreed that the employer shall give the employee a verbal warning on the first such violation, followed by a written warning for a maximum of two such similar offences thereafter. Failure to comply with such written warning by the employee shall result in the employee moving into the category III of the Disciplinary Code and such employee shall therefore be liable to face such disciplinary action as provided under the aforesaid category.

CATEGORY III:

This category of offence would include drinking on duty, being under the influence of alcohol or habit-forming drugs, desertion. The parties have agreed that this category of offence shall result in immediate suspension for the period of one month without pay and a written warning and subsequent dismissal if any one of the aforesaid offences or such similar offence is repeated by the employee after such written warning from the employer.

CATEGORY IV:

This category would include offences that would result in the employer suffering substantial loss or the Laws of Zambia being contravened. This category of offence would include such offences as theft, fraud and corruption and any such similar offences. The corrective action to be taken under this category by the employer would be the dismissal of the said employee.

P.E.Golson
SECRETARY TO THE JOINT COUNCIL FOR THE BUILDING AND CIVIL ENGINEERING INDUSTRY.

In witness whereof the parties hereto set their hands on the

For and on behalf of the National Union of Building Engineering & General Workers.

Deputy President:- Astridah Lwani

General Secretary:- Bryson Nyirenda

Director for Organisation Secretary:- Enos Cheelo

For and on behalf of the Association of Building and Civil Engineering Contractors.

ABCEC Executive Member:-

ABCEC JIC Member:-

ABCEC Executive Member:-Colin Dunn

Appendix E: List of materials used in road construction

S/No.	Description	Unit	Price (K)
M-001	Stone Boulder of size 150 mm and below at Crusher Plant	m3	67.16
M002	Boulder with minimum size of 300 mm for Pitching at Site	m3	67.16
M-003	Coarse sand at Mixing Plant	m3	34.63
M-004	Coarse sand at Site	m3	34.63
M-005	Fine sand at Site	m3	33.70
M-007	Gravel/Quarry spall at Site	m3	67.16
M-008	Granular Material	m3	32.54
M-009	Filter media/Filter Material	m3	141.53
M-010	Close graded Granular sub-base Material 9.5 mm to 53 mm	m3	130.49
M011	Close graded Granular sub-base Material 9.5 mm to 37.5 mm	m3	130.49
M012	Close graded Granular sub-base Material 9.5 mm to 26.5 mm	m3	136.54
M013	Close graded Granular sub-base Material 4.75 mm to 9.5mm	m3	178.60
M014	Close graded Granular sub-base Material 2.36 mm to 9.5mm	m3	178.60
M015	Close graded Granular sub-base Material 2.36 mm to 4.75mm	m3	119.11
M-019	Close graded Granular sub-base Material 75 micron mm to 4.75mm	m3	119.11
M-020	Close graded Granular sub-base Material 2.36 mm	m3	119.11
M-021	Stone crusher dust finer than 3mm with not more than 10% passing 0.075 sieve	m3	92.00
M-022	Coarse graded Granular sub-base Material 2.36 mm & below	m3	92.00
M-023	Coarse graded Granular sub-base Material 75 micron mm to 4.75mm	m3	92.00
M-024	Coarse graded Granular sub-base Material 2.36 mm to 4.75 mm	m3	141.53
M-025	Coarse graded Granular sub-base Material 4.75 mm to 9.5 mm	m3	141.53
M-026	Coarse graded Granular sub-base Material 4.75 mm to 26.5 mm	m3	120.30
M-027	Coarse graded Granular sub-base Material 9.5 mm to 26.5 mm	m3	102.29
M-028	Coarse graded Granular sub-base Material 9.5 mm to 37.5 mm	m3	96.24
M-029	Coarse graded Granular sub-base Material 26.5 mm to 53mm	m3	96.24
M-030	Aggregates below 5.6 mm	m3	84.92
M-031	Aggregates 2.36 mm to 22.4 mm	m3	109.37
M032	Aggregates 5.6 mm to 22.4 mm	m3	109.37
M-033	Aggregates 2.8 mm to 45 mm	m3	92.64
M-034	Aggregates 22.4 mm to 45 mm	m3	92.64
M-035	Aggregates 2.8 mm to 53 mm	m3	87.49
M-036	Aggregates 22.4 mm to 53 mm	m3	87.49
M-037	Aggregates 2.8 mm to 63 mm	m3	86.21
M-038	Aggregates 45 mm to 63 mm	m3	86.21
M-039	Aggregates 45 mm to 90 mm	m3	86.21
M-040	Aggregates 5 mm to 10 mm	m3	99.07
M-041	Aggregates 0.09 mm to 11.2 mm	m3	128.67
M-042	Aggregates 0.09 mm to 13.2 mm	m3	128.67
M-043	Aggregates 5.6 mm to 13.2 mm	m3	128.67
M-044	Aggregates 10 mm to 13.2 mm	m3	128.67
M-045	Aggregates 10 mm to 25 mm	m3	109.37
M-046	Aggregates 10 mm to 20 mm	m3	109.37
M-047	Aggregates 6 mm to 19 mm	m3	109.37
M-048	Aggregates 19 mm to 37.5mm	m3	109.37
M-049	Aggregates 25 mm to 37.5mm	m3	92.64
M-050	Aggregates 6 mm nominal size	m3	99.07
M-051	Aggregates 10 mm nominal size	m3	128.67
M-052	Aggregates 13.2/12.5 mm nominal size	m3	128.67
M-053	Aggregates 20 mm nominal size	m3	109.37
M-054	Aggregates 25 mm nominal size	m3	109.37
M-055	Aggregates 40 mm nominal size	m3	92.64
M-056	AC pipe 100 mm dia	m	19.01
M-058	Aluminium Paint	litre	64.65
M-059	Aluminium alloy plate 2mm Thick	m2	63.38
M-060	Aluminium alloy/galvanised steel	tonne	9,476.36
M-061	Aluminium sheeting fixed with encapsulated lens type reflective	m2	1,901.48

S/No.	Description	Unit	Price (K)
M-066	Bearing (Elastomeric bearing assembly consisting of 7 internal layers of elastomer bonded to 6 nos. internal reinforcing steel laminates by the process of vulcanisation,)	No.	7,289.02
M-068	Bearing (Pot type bearing assembly consisting of a metal piston supported by a disc, PTFE pads providing sliding surfaces against stainless steel mating together with cast steel assemblies/fabricated structural steel assemblies duly painted with all components	No.	38,029.68
M-069	Bearing (PTFE sliding plate bearing assembly of 80 tonnes)	No.	9,507.42
M-071	Bentonite	kg	0.65
M-072	Binding wire	kg	12.36
M-074	Bitumen (60-70 grade)	tonne	$1,200.00
M-075	CRMB-55	tonne	$1,223.00
M-076	Bitumen (emulsion - SS1)	tonne	$1,400.00
M-077	Bitumen (emulsion-RS1)	tonne	$1,400.00
M-078	Bitumen (modified graded)	tonne	$1,400.00
M-079	Concrete brick	each	1.00
M-079	Hollow concrete blocks 200mm	each	4.00
M-079	Hollow concrete blocks 150mm	each	3.00
M-079	Hollow concrete blocks 100mm	each	2.00
M-080	C.I. shoes for the pile	kg	25.35
M-081	Cement	tonne	1,394.42
M-082	Cold twisted bars (HYSD Bars)	tonne	9,476.36
M-083	Collar for joints 300 mm dia	No.	316.91
M-084	Compressible Fibre Board(20mm thick)	m2	19.01
M-087	Corrosion resistant Structural steel	tonne	9,476.36
M-089	Credit for excavated rock found suitable for use	m3	46.90
M-090	Curing compound	litre	6.34
M-091	Delineators as per the standard drawing	each	190.15
M-092	Earth Cost or compensation for earth taken from private land	m3	3.17
M-094	Electric Detonators @ 1 detonator for 1/2 gelatin stick of 125g each	100 no.	443.68
M-095	Epoxy compound with accessories for preparing epoxy mortar	kg	63.38
M-097	Epoxy primer (Sealant Primer)	kg	9.51
M-101	Galvanised MS flat clamp	No.	3.17
M-103	Galvanised structural steel plate 200 mm wide, 6 mm thick, 24 m long	kg	9.76
M-104	Gelatin 80%	kg	31.69
M-110	GI bolt 10 mm Dia	No.	0.48
M-111	Grouting pump with agitator	hour	72.89
M-118	Hot applied thermoplastic compound	litre	54.51
M-119	HTS strand	tonne	11,091.99
M-120	Joint Sealant Compound	kg	15.85
M-123	M.S. Clamps	No.	1.27
M-124	M.S. Clamps	kg	12.04
M-126	Mild Steel bars	tonne	9,476.36
M-130	Nuts and bolts	kg	15.53
M-131	Paint	litre	41.91
M-132	Pavement Marking Paint	litre	41.91
M-137	Pipes 200 mm dia, 2.5 m long for drainage	metre	186.98
M-138	Plastic sheath, 1.25 mm thick for dowel bars	m2	28.52
M-141	Pre moulded Joint filler 25 mm thick for expansion joint.	m2	25.35
M-142	Pre-coated stone chips of 13.2 mm nominal size	m3	1,267.66
M-144	Pre-moulded asphalt filler board	m2	19.01
M-145	Pre-packed cement based polymer concrete of strength 45 MPA at 28 days	kg	63.38
M-147	Quick setting compound	kg	50.71
M-148	Random Rubble Stone	m3	91.59
M-149	Culvert pipe 1200 mm dia (2.4m long)	m	1,183.26
M-150	Culvert pipe 1000 mm dia	m	888.66
M-150	Culvert pipe 900 mm dia	m	966.67
M-150	Culvert pipe 600 mm dia	m	508.00

S/No.	Description	Unit	Price (K)
M-151	Culvert pipe 300 mm dia	m	214.27
M-152	Reflectorizing glass beads	kg	63.38
M-159	Sand bags (Cost of sand and Empty cement bag)	No.	1.58
M-163	Selected earth	m3	44.37
M-164	Separation Membrane of impermeable plastic sheeting 125 micron thick	m2	0.95
M-165	Sheathing duct	m	19.01
M-167	Sludge / Farm yard manure @ 0.18 m3 per 100 m2 at site of work for turfing	m3	15.85
M-169	Square Rubble Coarse Stone	m3	91.59
M-173	Steel helmet and cushion block on top of pile head during driving.	kg	38.03
M-174	Steel pipe 25 mm dia	m	35.00
M-175	Steel pipe 50 mm dia	m	45.00
M-176	Steel wire rope 20 mm	kg	18.00
M-177	Steel wire rope 40 mm	kg	22.00
M-178	Strip seal expansion join	m	2,725.46
M-179	Structural Steel	tonne	9,710.24
M-180	Super plastisizer admixture IS marked as per 9103-1999	kg	12.68
M-181	Synthetic Geogrids as per clause 3102.8 and approved design and specification	m2	14.58
M-182	Through and bond stone	each	31.69
M-187	Tube anchorage set complete with bearing plate, permanent wedges etc	No.	102.05
M-188	Unstacked lime	tonne	3,486.05
M-189	Water	Litre	3.17
M-190	Water based cement paint	litre	9.19
M-192	Wire mesh 50mm x 50mm size of 3mm wire	kg	16.48
M-193	Precast box culvert 1200mm	m	1,696.00
M-194	Guard rails	m	
M-195	Kerbs	m	

Appendix F: All in Equipment rate detailed calculations using the caterpillar method

Equipment Basic Rates

Cost of Owning and Operating Construction Equipment: **Caterpillar Method**

Average working weeks in a year	44.6
Average working hours in a year	2007
Finance charges (lending rate + 3%)	23
Insurance rate	7.5
Road tax %	1
Cost of diesel per litre	6.59
Less tire / consummable replacement costs	

**Purchase price is price landed in Zambia*

										Owning Costs 'ZMW/hr						Operating costs 'ZMW/hr			
S/No.	**Description**	**Utilization Factor %**	**Hours per annum**	**Plant period (years)**	**Life (Hours)**	***Purchase price 'ZMW**	**Percent for consummable replacement costs**	**Less tire / consummable replacement costs**	**Nett value**	**Depreciation**	**Interest**	**Insurance**	**licence tax**	**Sub total**	**Fuel / oil Litres/hr**	**Fuel / oil consumption**	**Maintenance**	**Sub total**	**Total Owning & Operating costs / hr**
	Air Compressor 250 cfm with 2 leads of pneumatic breaker	85	1,705.95	9	15,353.55	25,000.00	3	750.00	24,250.00	1.58	1.82	0.59	0.08	4.07	9	59.31	0.44	59.75	63.82
	Batching and Mixing Plant (a) 30 m3 capacity	65	1,304.55	6	7,827.30	1,033,500.00	5	51,675.00	981,825.00	125.44	100.98	32.93	4.39	263.73	5	32.95	39.61	72.56	336.29
	Batching and Mixing Plant (b) 15 - 20 m3 capacity	65	1,304.55	6	7,827.30	838,500.00	5	41,925.00	796,575.00	101.77	81.92	26.71	3.56	213.97	5	32.95	32.14	65.09	279.06
	Batch type cold mixing plant 100-120 TPH capacity producing an average output of 75 tonne per hour																		
	Belt conveyor system																		
	Bitumen Pressure Distributor	65	1,304.55	6	7,827.30	166,355.00	5	8,317.75	158,037.25	20.19	16.25	5.30	0.71	42.45	17	112.03	6.38	118.41	160.86
	Bitumen Boiler oil fired	65	1,304.55	6	7,827.30	5,000.00	3	150.00	4,850.00	0.62	0.50	0.16	0.02	1.30	4.2	27.68	0.11	27.79	29.10
	Boat ???																		
	Cement concrete batch mix plant @ 175 cum per hour (effective output)																		
	Cement concrete batch mix plant @ 75 cum per hour																		
	Concrete Paver Finisher with 40 HP Motor	65	1,304.55	6	7,827.30	1,105,272.00	5	55,263.60	1,050,008.40	134.15	107.99	35.21	4.70	282.04	16	105.44	42.36	147.80	429.85
	Concrete Pump of 45 & 30 m3 capacity	65	1,304.55	6	7,827.30	38,000.00	3	1,140.00	36,860.00	4.71	3.79	1.24	0.16	9.90	4.2	27.68	0.87	28.55	38.45
	Concrete Bucket	100	2,007.00	5	10,035.00	10,000.00	2	200.00	9,800.00	0.98	0.67	0.22	0.03	1.90	0	-	0.10	0.10	2.00
	Concrete Mixer (a) 0.4/0.28 m3	85	1,705.95	7	11,941.65	160,000.00	2	3,200.00	156,800.00	13.13	12.08	3.94	0.53	29.67	1.2	7.91	1.88	9.78	39.46
	Concrete Mixer (b) 1 m3	85	1,705.95	7	11,941.65	180,000.00	2	3,600.00	176,400.00	14.77	13.59	4.43	0.59	33.38	1.2	7.91	2.11	10.02	43.40
	Crane (a) 80 tonnes	60	1,204.20	15	18,063.00	226,870.00	10	22,687.00	204,183.00	11.30	20.80	6.78	0.90	39.79	21	138.39	18.84	157.23	197.02
	Cranes (b) 35 tonnes	60	1,204.20	15	18,063.00	256,270.00	10	25,627.00	230,643.00	12.77	23.49	7.66	1.02	44.95	9.3	61.29	21.28	82.57	127.51
	Cranes (c) 5tonnes																		
	Cranes (d) 3 tonnes	60	1,204.20	12	14,450.40	88,690.00	10	8,869.00	79,821.00	5.52	8.26	2.69	0.36	16.83	5.1	33.61	7.37	40.97	57.81
	Crane with grab 0.75 cum capacity																		
	Dozer D - 80 - A 12	78	1,565.46	10	15,654.60	1,289,484.00	6	77,369.04	1,212,114.96	77.43	97.95	31.94	4.26	211.57	38	250.42	49.42	299.84	511.42
	Dozer D - 50 - A 15	78	1,565.46	10	15,654.60	1,230,684.00	3	36,920.52	1,193,763.48	76.26	96.46	31.46	4.19	208.37	21	138.39	23.58	161.97	370.35
	Emulsion Pressure Distributor	65	1,304.55	6	7,827.30	158,270.00	5	7,913.50	150,356.50	19.21	15.46	5.04	0.67	40.39	11	72.49	6.07	78.56	118.94
	Front End loader 1 m3 bucket capacity	80	1,605.60	9	14,450.40	128,576.00	4	5,143.04	123,432.96	8.54	9.82	3.20	0.43	22.00	18	118.62	3.20	121.82	143.82
	Generator (a) 100/125 KVA	85	1,705.95	5	8,529.75	164,892.00	5	8,244.60	156,647.40	18.36	12.67	4.13	0.55	35.72	9.8	64.58	4.83	69.41	105.13
	Generator(b) 33/63 KVA	85	1,705.95	5	8,529.75	103,978.00	3	3,119.34	100,858.66	11.82	8.16	2.66	0.35	23.00	4.9	32.29	1.83	34.12	57.12
	GSB Plant 50 m3	65	1,304.55	6	7,827.30	172,235.00	5	8,611.75	163,623.25	20.90	16.83	5.49	0.73	43.95	16	105.44	6.60	112.04	155.99
	Hotmix Plant - 120 TPH capacity	65	1,304.55	6	7,827.30	###########	5	578,974.20	###########	1,405.40	1,131.35	368.92	49.19	2,954.86	16	105.44	443.81	549.25	3504.11
	Hotmix Plant - 100 TPH capacity	65	1,304.55	6	7,827.30	8,639,484.00	5	431,974.20	8,207,509.80	1,048.57	844.10	275.25	36.70	2,204.63	16	105.44	331.13	436.57	2641.20
	Hotmix Plant - 60 to 90 TPH capacity	65	1,304.55	6	7,827.30	6,777,484.00	5	338,874.20	6,438,609.80	822.58	662.18	215.93	28.79	1,729.48	16	105.44	259.76	365.20	2094.69
	Hotmix Plant - 40 to 60 TPH capacity	65	1,304.55	6	7,827.30	5,209,484.00	5	260,474.20	4,949,009.80	632.28	508.98	165.97	22.13	1,329.36	16	105.44	199.67	305.11	1634.47
	Hydraulic Chip Spreader	65	1,304.55	7	9,131.85	1,059,500.00	5	52,975.00	1,006,525.00	110.22	101.40	33.07	4.41	249.10	16	105.44	40.61	146.05	395.15
	Hydraulic Excavator of 1 m3 bucket	80	1,605.60	9	14,450.40	403,270.00	4	16,130.80	387,139.20	26.79	30.81	10.05	1.34	68.99	18	118.62	10.05	128.67	197.65
	Integrated Stone Crusher 100THP	65	1,304.55	6	7,827.30	4,062,884.00	5	203,144.20	3,859,739.80	493.11	396.96	129.44	17.26	1,036.77	16	105.44	155.72	261.16	1297.93
	Integrated Stone Crusher 200 HP	65	1,304.55	6	7,827.30	9,031,484.00	5	451,574.20	8,579,909.80	1,096.15	882.40	287.74	38.37	2,304.66	16	105.44	346.15	451.59	2756.25
	Kerb Casting Machine	75	1,505.25	7	10,536.75	57,918.00	5	2,895.90	55,022.10	5.22	4.80	1.57	0.21	11.80	5	32.95	1.92	34.87	46.68
	Mastic Cooker	65	1,304.55	6	7,827.30	767,000.00	5	38,350.00	728,650.00	93.09	74.94	24.44	3.26	195.72	17	112.03	29.40	141.43	337.15
	Mechanical Broom Hydraulic	85	1,705.95	9	15,353.55	108,878.00	5	5,443.90	103,434.10	6.74	7.75	2.53	0.34	17.35	5	32.95	3.19	36.14	53.49

S/No.	Description	Utilization Factor %	Hours per annum	Plant period (years)	Life (Hours)	*Purchase price 'ZMW	Percent for consummable replacement costs	Less tire / consummable replacement costs	Nett value	Owning Costs 'ZMW/hr Depreciation	Interest	Insurance	licence tax	Sub total	Fuel / oil Litres/hr	Operating costs 'ZMW/hr Fuel / oil consumption	Maintenance	Sub total	Total Owning & Operating costs / hr	
	Motor Grader complete with scarifier, CAT 14 or equivalent	78	1,565.46	10	15,654.60	862,250.00	5	43,112.50	819,137.50	52.33	66.19	21.58	2.88	142.98	19	125.21	27.54	152.75	295.73	
	Mobile slurry seal equipment	65	1,304.55	6	7,827.30	437,724.00	5	21,886.20	415,837.80	53.13	42.77	13.95	1.86	111.70	9	59.31	16.78	76.09	187.79	
	Paver Finisher Hydrostatic with sensor control 100 TPH	65	1,304.55	7	9,131.85	1,105,272.00	5	55,263.60	1,050,008.40	114.98	105.78	34.49	4.60	259.86	16	105.44	42.36	147.80	407.66	
	Paver Finisher Mechanical 100 TPH	65	1,304.55	7	9,131.85	269,724.00	5	13,486.20	256,237.80	28.06	25.82	8.42	1.12	63.42	16	105.44	10.34	115.78	179.19	
	Piling Rig with Bantonite Pump	65	1,304.55	7	9,131.85	2,608,872.00	10	260,887.20	2,347,984.80	257.12	236.55	77.14	10.28	581.09	6.3	41.52	199.98	241.50	822.59	
	Piling rig Including double acting pile driving hammer (Hydraulic rig)																			
	Pneumatic Road Roller	75	1,505.25	6	9,031.50	513,324.00	7.5	38,499.30	474,824.70	52.57	42.32	13.80	1.84	110.54	7.6	50.08	25.58	75.66	186.20	
	Pneumatic Sinking Plant	65	1,304.55	6	7,827.30	2,020,872.00	5	101,043.60	1,919,828.40	245.27	197.45	64.38	8.58	515.69	5	32.95	77.45	110.40	626.09	
	Pot Hole Repair Machine	78	1,565.46	7	10,958.22	454,524.00	5	22,726.20	431,797.80	39.40	36.25	11.82	1.58	89.05	5	32.95	14.52	47.47	136.52	
	Prestressing Jack with Pump & access	65	1,304.55	6	7,827.30	9,898.00	2	197.96	9,700.04	1.24	1.00	0.33	0.04	2.61	2.5	16.48	0.15	16.63	19.23	
	Ripper	100	2,007.00	7	14,049.00	5,978.00	0.5	29.89	5,948.11	0.42	0.39	0.13	0.02	0.96	0.5	3.30	0.01	3.31	4.27	
	Rotavator	100	2,007.00	7	14,049.00	3,038.00	0.5	15.19	3,022.81	0.22	0.20	0.06	0.01	0.49	0.3	1.98	0.01	1.98	2.47	
	Road marking machine	85	1,705.95	7	11,941.65	6,958.00	2.8	194.82	6,763.18	0.57	0.52	0.17	0.02	1.28	1.8	11.86	0.11	11.98	13.26	
	Smooth Wheeled Roller 8 tonne	85	1,705.95	6	10,235.70	9,555.00	7.5	716.63	8,838.38	0.86	0.70	0.23	0.03	1.82	17	112.03	0.42	112.45	114.27	
	Tandem Road Roller	85	1,705.95	6	10,235.70	256,270.00	7.5	19,220.25	237,049.75	23.16	18.64	6.08	0.81	48.69	17	112.03	11.27	123.30	171.99	
	Tipper - 5 m3	90	1,806.30	6	10,837.80	226,870.00	3	6,806.10	220,063.90	20.31	16.35	5.33	0.71	42.69	17	112.03	3.77	115.80	3.96	m3/km
	Tipper - 5 m3	90	1,806.30	6	10,837.80	226,870.00	3	6,806.10	220,063.90	20.31	16.35	5.33	0.71	42.69	17	112.03	3.77	115.80	19.81	km
	Tipper - 5 m3	90	1,806.30	6	10,837.80	226,870.00	3	6,806.10	220,063.90	20.31	16.35	5.33	0.71	42.69	17	112.03	3.77	115.80	158.49	hr
	Tipper 5.5 m3 per 10tonnes 4 trips/hour	90	1,806.30	6	10,837.80	226,870.00	3	6,806.10	220,063.90	20.31	16.35	5.33	0.71	42.69	17	112.03	3.77	115.80	3.60	m3/km
	Tipper - 10T	90	1,806.30	6	10,837.80	226,870.00	3	6,806.10	220,063.90	20.31	16.35	5.33	0.71	42.69	17	112.03	3.77	115.80	158.49	
		90	1,806.30	6	10,837.80	226,870.00	3	6,806.10	220,063.90	20.31	16.35	5.33	0.71	42.69	17	112.03	3.77	115.80	19.81	km
	Tipper - 20T	90	1,806.30	6	10,837.80	324,870.00	3	9,746.10	315,123.90	29.08	23.41	7.63	1.02	61.13	17	112.03	5.40	117.43	178.56	
	Transit Mixer 4/4.5 m3	75	1,505.25	7	10,536.75	124,019.00	3	3,720.57	120,298.43	11.42	10.50	3.43	0.46	25.80	17	112.03	2.47	114.50	140.30	
	Transit Mixer 4/4.5 m4	75	1,505.25	7	10,536.75	124,019.00	3	3,720.57	120,298.43	11.42	10.50	3.43	0.46	25.80	17	112.03	2.47	114.50	3.90	m3/km
	Transit Mixer 3.0 m2	75	1,505.25	7	10,536.75	95,599.00	3	2,867.97	92,731.03	8.80	8.10	2.64	0.35	19.89	17	112.03	1.91	113.94	3.72	m3/km
	Transit Mixer 3.0 m3	75	1,505.25	7	10,536.75	95,599.00	3	2,867.97	92,731.03	8.80	8.10	2.64	0.35	19.89	17	112.03	1.91	113.94	133.82	
	Tractor	86	1,726.02	7	12,082.14	79,000.00	2	1,580.00	77,420.00	6.41	5.90	1.92	0.26	14.48	9	59.31	0.92	60.23	74.71	
	Tractor with Rotevator	86	1,726.02	7	12,082.14	82,038.00	2	1,640.76	80,397.24	6.65	6.12	2.00	0.27	15.04	9	59.31	0.95	60.26	75.30	
	Tractor with Ripper	86	1,726.02	7	12,082.14	84,978.00	2	1,699.56	83,278.44	6.89	6.34	2.07	0.28	15.58	9	59.31	0.98	60.29	75.87	
	Truck 5.5 m3 per 10 tonnes	86	1,726.02	6	10,356.12	226,870.00	3	6,806.10	220,063.90	21.25	17.11	5.58	0.74	44.68	17	112.03	3.94	115.97	160.65	
	Vibratory Roller 8 tonne	85	1,705.95	6	10,235.70	704,914.00	7.5	52,868.55	652,045.45	63.70	51.28	16.72	2.23	133.94	7.6	50.08	30.99	81.07	215.01	
	Water Tanker	75	1,505.25	7	10,536.75	256,270.00	2	5,125.40	251,144.60	23.84	21.93	7.15	0.95	53.87	9	59.31	3.41	62.72	116.58	
	Wet Mix Plant 60 TPH	65	1,304.55	6	7,827.30	530,670.00	2	10,613.40	520,056.60	66.44	53.49	17.44	2.33	139.69	5	32.95	8.14	41.09	180.78	
	Wet Mix Plant 75 TPH																			
	Epoxy Injection gun	100	2,007.00	5	10,035.00	99,470.00	5	4,973.50	94,496.50	9.42	6.50	2.12	0.28	18.32	1	6.59	2.48	9.07	27.38	
	Plate compactor	85	1,705.95	9	15,353.55	9,310.00	3	279.30	9,030.70	0.59	0.68	0.22	0.03	1.51	9	59.31	0.16	59.47	60.99	
	620HP RX-600e/ex Asphalt Milling Machine with a two-stage front loadout conveyor with 60° swing							-												
	CAT RM 300 road reclaimer																			

Appendix G: Detailed base rate calculations from first principles

SERIES 3000: EARTHWORKS AND PAVEMENT LAYERS OF GRAVEL OR CRUSHED STONE								
Series	**Ref Spec.**		**Description**	**Unit**	**Quantity**	**Rate**	**Cost**	**Rate per unit**
3100			**BORROW MATERIAL**					
	31.01		**Excess overburden in borrow pits for obtaining crushed stone for pavement layers:**					
		(a)	**Overburden in soft or intermediate excavation**					
			Unit = m3					
			Taking output = 120 m3					
			Labour					
			Foreman	day	2.800			
			Labourer	day	70.000			
			Machinery					
			Truck 5.5 m3 capacity	hour	10.000			
		Note	-Removal of top soil see series 5700 -Clearing and grubbing of borrow areas will be measured for payment in accordance with the provisions of Section 1700					
		(b)	**Overburden in hard excavation**					
			Unit = m3					
			Taking output = 180 m3					
			a) Labour					
			Foreman	day	0.080			
			Labourer	day	2.000			
			b) Machinery					
			Dozer, 80 HP @ 30 m3 per hour	hour	6.000			

Series	Ref Spec.		Description	Unit	Quantity	Rate	Cost	Rate per unit
3300			**MASS EARTHWORKS**					
	33.01		**Cut and borrow to fill, including free-haul up to 0.5 km:**					
		(a)	**Gravel material in compacted layer thicknesses of 200 mm and less:**					
		(i)	**Compacted to 90% of modified AASHTO density**					
		Note	Compensation for earth will vary from place to place and will have to be assessed realistically as per particular ground situation. In case earth is available from Govt. land, compensation for earth will not be required. The position is required to be clearly stated in the cost estimate.					
			Unit = m3					
			Taking output = 100 m3					
			Labour					
			Foreman	day	0.020			
			Labourer	day	0.500			
			Machinery					
			Dozer 80 HP for spreading @ 200 m3 per hour	hour	0.500			
			Motor grader for grading @ 100 m3 per hour	hour	1.000			
			Water tanker 6000L capacity	hour	4.000			
			Vibratory roller 8-10 tonnes @ 100 m3 per hour	hour	1.000			
			Material					
			Cost of water	L	24000			
		(ii)	**Compacted to 93% of modified AASHTO density**					
			Unit = m3					
			Taking output = 100 m3					
			a) Labour					
			Foreman	day	0.030			
			Labourer	day	0.750			
			b) Machinery					
			Dozer 80 HP for spreading @ 200 m3 per hour	hour	0.500			
			Motor grader for grading @ 100 m3 per hour	hour	1.500			
			Water tanker 6000L capacity	hour	6.000			
			Vibratory roller 8-10 tonnes @ 100 m3 per hour	hour	1.500			
			c) Material					
			Cost of water	L	36000			
		(iii)	**Twelve roller passes compaction**					
		Note:	One roller does 1860m2 of consolidation per day of 8 hours and uses 18 litres diesel					
			Unit = m3					
			Taking output = 100 m3					
			Labour					
			Foreman	day	0.020			
			Labourer	day	0.500			
			Machinery					
			Dozer 80 HP for spreading @ 200 m3 per hour	hour	0.500			
			Motor grader for grading @ 100 m3 per hour	hour	1.000			

Series	Ref Spec.		Description	Unit	Quantity	Rate	Cost	Rate per unit
			Water tanker 6000L capacity	hour	4.000			
			Vibratory roller 8-10 tonnes @ 100 m3 per hour	hour	1.000			
			Material					
			Cost of water	L	24000			
		(b)	**Gravel material in compacted layer thicknesses from 200 mm to 500 mm:**					
		(i)	**Compacted to 90% of modified AASHTO density**					
			Unit = m3					
			Taking output = 100 m3					
			Labour					
			Foreman	day	0.040			
			Labourer	day	1.000			
			Machinery					
			Dozer 80 HP for spreading @ 200 m3 per hour	hour	0.500			
			Motor grader for grading @ 100 m3 per hour	hour	2.000			
			Water tanker 6000L capacity	hour	4.000			
			Vibratory roller 8-10 tonnes @ 100 m3 per hour	hour	1.250			
			Material					
			Cost of water	L	24000			
		(ii)	**Compacted to 93% of modified AASHTO density**					
			Unit = m3					
			Taking output = 100 m3					
			a) Labour					
			Foreman	day	0.060			
			Labourer	day	1.500			
			b) Machinery					
			Dozer 80 HP for spreading @ 200 m3 per hour	hour	0.750			
			Motor grader for grading @ 100 m3 per hour	hour	3.000			
			Water tanker 6000L capacity	hour	6.000			
			Vibratory roller 8-10 tonnes @ 100 m3 per hour	hour	1.875			
			c) Material					
			Cost of water	L	36000			
		(iii)	**Twelve roller passes compaction**					
			Unit = m3					
			Taking output = 100 m3					
			Labour					
			Foreman	day	0.040			
			Labourer	day	1.000			
			Machinery					
			Dozer 80 HP for spreading @ 200 m3 per hour	hour	0.500			
			Motor grader for grading @ 100 m3 per hour	hour	2.000			
			Water tanker 6000L capacity	hour	4.000			
			Vibratory roller 8-10 tonnes @ 100 m3 per hour	hour	1.250			
			Material					
			Cost of water	L	24000			

Series	Ref Spec.		Description	Unit	Quantity	Rate	Cost	Rate per unit
		(c)	**Rock fill (as specified in Subclause 3209(c))**					
		(d)	**Rock protection at the toes of fills**					
		(e)	**Pioneer layer**					
			Unit = m3					
			Taking output = 100 m3					
			a) Labour					
			Foreman	day	0.040			
			Labourer	day	1.000			
			b) Machinery					
			Hydraulic Excavator1 m3 bucket capacity @ 60 m3 per hour	hour	1.670			
			Tipper 10 tonne capacity	tonne.km	160 x			
			Add 10 per cent of cost of carriage to cover					
			Dozer 80 HP for spreading @ 200 m3 per hour	hour	0.500			
			Motor grader for grading @ 100 m3 per hour	hour	1.000			
			Water tanker 6000L capacity	hour	4.000			
			Vibratory roller 8 -10 tonnes @ 100 m3 per hour	hour	1.000			
			c) Material					
			Cost of water	L	24000			
			Compensation for earth taken from private land	m3	100.000			
		(f)	**Sand filter blanket**					
			Unit = m3					
			Taking output = 100 m3					
			Labour					
			Foreman	day	0.040			
			Labourer	day	1.000			
			Machinery					
			Hydraulic Excavator1 m3 bucket capacity @ 60 m3 per hour	hour	1.670			
			Tipper 10 tonne capacity	tonne.km	160 x L			
			Add 10 per cent of cost of carriage to cover cost of loading and unloading					
			Dozer 80 HP for spreading @ 200 m3 per hour	hour	0.500			
			Motor grader for grading @ 100 m3 per hour	hour	1.000			
			Water tanker 6000 L capacity	hour	4.000			
			Vibratory roller 8 -10 tonnes @ 100 m3 per hour	hour	1.000			
			Material					
			Cost of water	L	24000			
			Compensation for sand taken from private land	m3	100.000			
	33.02		**Sand fills (as described in Clause 3302, including free-haul up to 0.5 km):**					
		(a)	**Non-plastic sand with up to 20% passing through the 0.075 mm sieve, compacted to 100% of modified AASHTO density**					
			Unit = m3					
			Taking output = 100 m3					
			Labour					
			Foreman	day	0.040			
			Labourer	day	1.000			
			Machinery					

Series	Ref Spec.		Description	Unit	Quantity	Rate	Cost	Rate per unit
			Hydraulic Excavator1 m3 bucket capacity @ 60 m3 per hour	hour	1.670			
			Tipper 10 tonne capacity	tonne.km	160 x L			
			Add 10 per cent of cost of carriage to cover					
			Dozer 80 HP for spreading @ 200 m3 per hour	hour	0.500			
			Motor grader for grading @ 100 m3 per hour	hour	1.000			
			Water tanker 6000 L capacity	hour	4.000			
			Vibratory roller 8 -10 tonnes @ 100 m3 per hour	hour	1.000			
			Material					
			Cost of water	L	24000			
			Non-plastic sand with up to 20%	m3	100.000			
		(b)	**Non-plastic sand with more than 20% passing through the 0.075 mm sieve, compacted to 95% of modified AASHTO density**					
			Unit = m3					
			Taking output = 100 m3					
			Labour					
			Foreman	day	0.060			
			Labourer	day	1.500			
			Machinery					
			Hydraulic Excavator1 m3 bucket capacity @ 60 m3 per hour	hour	2.505			
			Tipper 10 tonne capacity	tonne.km	240 x L			
			Add 10 per cent of cost of carriage to cover					
			Dozer 80 HP for spreading @ 200 m3 per hour	hour	0.750			
			Motor grader for grading @ 100 m3 per hour	hour	1.500			
			Water tanker 6000 L capacity	hour	6.000			
			Vibratory roller 8 -10 tonnes @ 100 m3 per hour	hour	1.500			
			Material					
			Cost of water	L	36000			
			Non-plastic sand with more 20%	m3	150.000			
	33.03		**Extra over Item 33.01 for excavating and breaking down material in:**					
		(a)	**Intermediate excavation**					
			Unit = m3					
			Taking output = 108 m3					
			Machinery					
			Dozer, 80 HP @ 20 m3 per hour	hour	6.000			
		(b)	**Hard excavation**					
			Unit = m3					
			Taking Output = 180 m3					
			Machinery					
			Dozer, 80 HP @ 30 m3 per hour	hour	6.000			
			Air compressor, 250 cfm with 2 jack hammers	hour	6.000			
			Front end loader 1 m3 bucket capacity	hour	6.000			
			Tipper 5.5 m3 capacity, 4 trips per hour.	hour	8.200			
			Materials					
			Gelatin 80 per cent	kg	63.000			
			Electric Detonators @ 1 detonator for1/2 gelatin	each	1008.000			
			Credit for excavated rock found suitable for	m3	90.000			
		(c)	**Boulder excavation class A**					

Series	Ref Spec.		Description	Unit	Quantity	Rate	Cost	Rate per unit
			Unit = m3					
			Taking output = 240 m3					
			Machinery					
			Hydraulic Excavator 0.90 m3 bucket capacity @ 36 m3 per hour	hour	6.000			
			Tipper 5.5 m3 capacity, 4 trips per hour.	hour	11.000			
		(d)	**Boulder excavation class B**					
			Unit = m3					
			Taking output = 240 m3					
			Machinery					
			Hydraulic excavator 0.9 m3 bucket capacity @ 60 m3 per hour	hour	6.000			
			Tipper 5.5 m3 capacity, 4 trips per hour.	hour	16.000			
	33.04		**Cut to spoil, including free-haul up to 0.5 km. Material obtained from:**					
		note	Excavation for roadwork in soil with hydraulic excavator of 0.9 m3 bucket capacity including cutting and loading in tippers, trimming bottom and side slopes, in accordance with requirements of lines, grades and cross sections, and transporting to the embankment location within all lifts and lead upto 1000m					
		(a)	**Soft excavation**					
			Unit = m3					
			Taking output = 360 m3					
			Labour					
			Foreman	day	0.080			
			Labourer	day	2.000			
			Machinery					
			Hydraulic excavator 0.9 m3 bucket capacity @	hour	6.000			
			Tipper 5.5 m3 capacity, 4 trips per hour.	hour	16.000			
		(b)	**Intermediate excavation**					
			Unit = m3					
			Taking output = 360 m3					
			Labour					
			Foreman	day	0.090			
			Labourer	day	2.100			
			Machinery					
			Hydraulic excavator 0.9 m3 bucket capacity @ 60 m3 per hour	hour	6.100			
			Tipper 5.5 m3 capacity, 4 trips per hour.	hour	16.100			
		(c)	**Hard excavation**					
			Unit = m3					
			Taking output = 300 m3					
			Labour					
			Foreman	day	0.080			
			Labourer	day	2.000			
			Machinery					
			Hydraulic excavator 0.90 m3 bucket capacity @ 50 m3 per hour	hour	6.000			
			Tipper 5.5 m3 capacity, 4 trips per hour.	hour	13.640			

Series	Ref Spec.		Description	Unit	Quantity	Rate	Cost	Rate per unit
		(d)	**Boulder excavation Class A**					
			Unit = m3					
			Taking output = 240 m3					
			a) Labour					
			Foreman	day	0.080			
			Labourer	day	2.000			
			b) Machinery					
			Hydraulic Excavator 0.90 m3 bucket capacity	hour	6.000			
			Tipper 5.5 m3 capacity, 4 trips per hour.	hour	11.000			
		(e)	**Boulder excavation Class B**					
			Unit = m3					
			Taking output = 36 m3					
			Labour					
			Foreman	day	0.400			
			Labourer for trimming slopes including mannul	day	10.000			
			Machinery					
			Hydraulic excavator with rock breaker	hour	6.000			
			Tipper 5.5 m3 capacity, 1 trip per hour.	hour	6.500			
			Credit for excavated rock found suitable for	m3	18.000			
		Note	1. The quality and availability of rock shall be					
			2. In case some rock is issued to the contractor at					
			3.Being small quantity, manual loading will be economical in this case and has been provided					
	33.07		**Removal of unsuitable material (including free-haul of 0.5 km):**					
		(a)	**In layer thicknesses of 200 mm and less:**					
			(i) Stable material					
			Unit = m3					
			Taking output = 360 m3					
			Labour					
			Foreman	day	0.080			
			Labourer	day	2.000			
			Machinery					
			Excavator0.90 m3 bucket capacity @ 60 m3 per hour	hour	6.000			
			Tipper 5.5 m3 capacity, 4 trips per hour.	hour	16.360			
			(ii) Unstable material					
			Unit = m3					
			Taking output = 360 m3					
			Labour					
			Foreman	day	0.090			
			Labourer	day	2.100			
			Machinery					
			Excavator0.90 m3 bucket capacity @ 60 m3 per hour	hour	6.100			
			Tipper 5.5 m3 capacity, 4 trips per hour.	hour	16.460			
		(b)	**In layer thicknesses exceeding 200 mm:**					
			(i) Stable material					
			Unit = m3					
			Taking output = 360 m3					

Series	Ref Spec.		Description	Unit	Quantity	Rate	Cost	Rate per unit
			Labour					
			Foreman	day	1.000			
			Labourer	day	3.000			
			Machinery					
			Excavator0.90 m3 bucket capacity @ 60 m3 per hour	hour	7.000			
			Tipper 5.5 m3 capacity, 4 trips per hour.	hour	17.360			
			(ii) Unstable material					
			Unit = m3					
			Taking output = 360 m3					
			Labour					
			Foreman	day	1.100			
			Labourer	day	3.100			
			Machinery					
			Excavator0.90 m3 bucket capacity @ 60 m3 per hour	hour	7.100			
			Tipper 5.5 m3 capacity, 4 trips per hour.	hour	17.460			
	33.08		**Widening of cuts (extra over Items 33.01, 33.02 and 33.04):**					
		(a)	**In hard material**					
			Unit = m3					
			Taking output = 360 m3					
			Machinery					
			Hydraulic excavator 0.9 m3 bucket capacity @	hour	6.000			
			Tipper 5.5 m3 capacity, 4 trips per hour.	hour	16.000			
		(b)	**In boulder material Class A or Class B**					
			Unit = m3					
			Taking output = 240 m3					
			Machinery					
			Hydraulic Excavator 0.90 m3 bucket capacity @ 36 m3 per hour	hour	6.000			
			Tipper 5.5 m3 capacity, 4 trips per hour.	hour	11.000			
		(c)	**In all other material**					
			Unit = m3					
			Taking output = 36 m3					
			Machinery					
			Hydraulic excavator with rock breaker	hour	6.000			
			Tipper 5.5 m3 capacity, 1 trip per hour.	hour	6.500			
	33.09		**Material bladed to windrow**					
	33.10		**Roadbed preparation and the compaction of material:**					
		(a)	**Compaction to 90% of modified AASHTO density**					
			Unit = m2					
			Taking output = 100 m2					
			a) Labour					
			Foreman	day	0.010			
			Labourer	day	0.250			
			b) Machinery					
			Tractor with ripper attachment @ 60 m3 per hour	hour	0.080			

Series	Ref Spec.		Description	Unit	Quantity	Rate	Cost	Rate per unit
			Front end loader 1 m3 bucket capacity @ 25 m3 per hour	hour	0.200			
			Tipper 5.5 m3 capacity, 4 trips per hour.	hour	0.230			
		(b)	**Compaction to 93% of modified AASHTO density**					
			Unit = m2					
			Taking output = 100 m2					
			a) Labour					
			Foreman	day	0.015			
			Labourer	day	0.375			
			b) Machinery					
			Tractor with ripper attachment @ 60 m3 per hour	hour	0.120			
			Front end loader 1 m3 bucket capacity @ 25 m3 per hour	hour	0.300			
			Tipper 5.5 m3 capacity, 4 trips per hour.	hour	0.345			
		(c)	**Compaction to 98% of proof density**					
			Unit = m2					
			Taking output = 100 m2					
			a) Labour					
			Foreman	day	0.0175			
			Labourer	day	0.4375			
			b) Machinery					
			Tractor with ripper attachment @ 60 m3 per hour	hour	0.140			
			Front end loader 1 m3 bucket capacity @ 25	hour	0.350			
			Tipper 5.5 m3 capacity, 4 trips per hour.	hour	0.4025			
	33.12		**In situ treatment of roadbed:**					
		(a)	**In situ treatment by ripping**					
			Unit = m2					
			Taking output = 100 m2					
			a) Labour					
			Foreman	day	0.010			
			Labourer	day	0.250			
			b) Machinery					
			Tractor with ripper attachment @ 60 m3 per hour	hour	0.080			
			Front end loader 1 m3 bucket capacity @ 25 m3 per hour	hour	0.200			
			Tipper 5.5 m3 capacity, 4 trips per hour.	hour	0.230			
		(b)	**In situ treatment by blasting**					
			Unit = m3					
			Taking Output = 180 m3					
			a) Labour					
			Foreman	day	0.220			
			Labourer	day	3.000			
			Driller	day	2.000			
			Blaster	day	0.250			
			b) Machinery					
			Dozer, 80 HP @ 30 m3 per hour	hour	6.000			
			Air compressor, 250 cfm with 2 jack hammer	hour	6.000			

Series	Ref Spec.		Description	Unit	Quantity	Rate	Cost	Rate per unit
			Front end loader 1 m3 bucket capacity	hour	6.000			
			Tipper10 tonne capacity	hour	11.250			
			c) Materials					
			Gelatin 80 per cent	kg	63.000			
			Electric Detonators @ 1 detonator for 2 gelatin sticks of 125 gms each	each	252.000			
			Credit for excavated rock found suitable for use @ 50 per cent quantity blasted	m3	90.000			
3400			**PAVEMENT LAYERS OF GRAVEL MATERIAL**					
	34.01		**Pavement layers constructed from gravel taken from cut or borrow, including free-haul up to 1.0 km:**					
		(a)	**Gravel selected layer compacted to :**					
		(i)	**90% of modified AASHTO density (specify compacted layer thickness)**					
			Thickness: 150mm					
			Unit = m3					
			Taking output = 300 m3					
			a) Labour					
			Foreman	day	0.400			
			Labourer skilled	day	2.000			
			Labourer	day	8.000			
			b) Machinery					
			Mortar Grader 110 HP @ 50 m3 per hour	hour	6.000			
			Vibratory roller 8 -10 tonne	hour	6.000			
			Water tanker 6000 L capacity	hour	3.000			
			c) Material					
			For close graded Granular sub-base Materials					
			Close graded 53mm to 26.5 mm @ 35%	m3	134.400			
			Close graded 26.5mm to 4.75mm @ 45%	m3	172.800			
			Close graded 2.36 mm below @ 20 per cent	m3	76.800			
			Cost of water	L	18000			
		(ii)	**93% of modified AASHTO density (specify compacted layer thickness)**					
			Thickness: 150mm					
			Unit = m3					
			Taking output = 300 m3					
			a) Labour					
			Foreman	day	0.600			
			Labourer skilled	day	6.600			
			Labourer	day	12.00			
			b) Machinery					
			Mortar Grader 110 HP @ 50 m3 per hour	hour	9.000			
			Vibratory roller 8 -10 tonne	hour	9.000			
			Water tanker 6000 L capacity	hour	4.500			
			c) Material					
			For close graded Granular sub-base Materials					
			Close graded 53mm to 26.5 mm @ 35%	m3	201.600			
			Close graded 26.5mm to 4.75mm @ 45%	m3	259.200			
			Close graded 2.36 mm below @ 20 per cent	m3	115.2			
			Cost of water	L	27000			

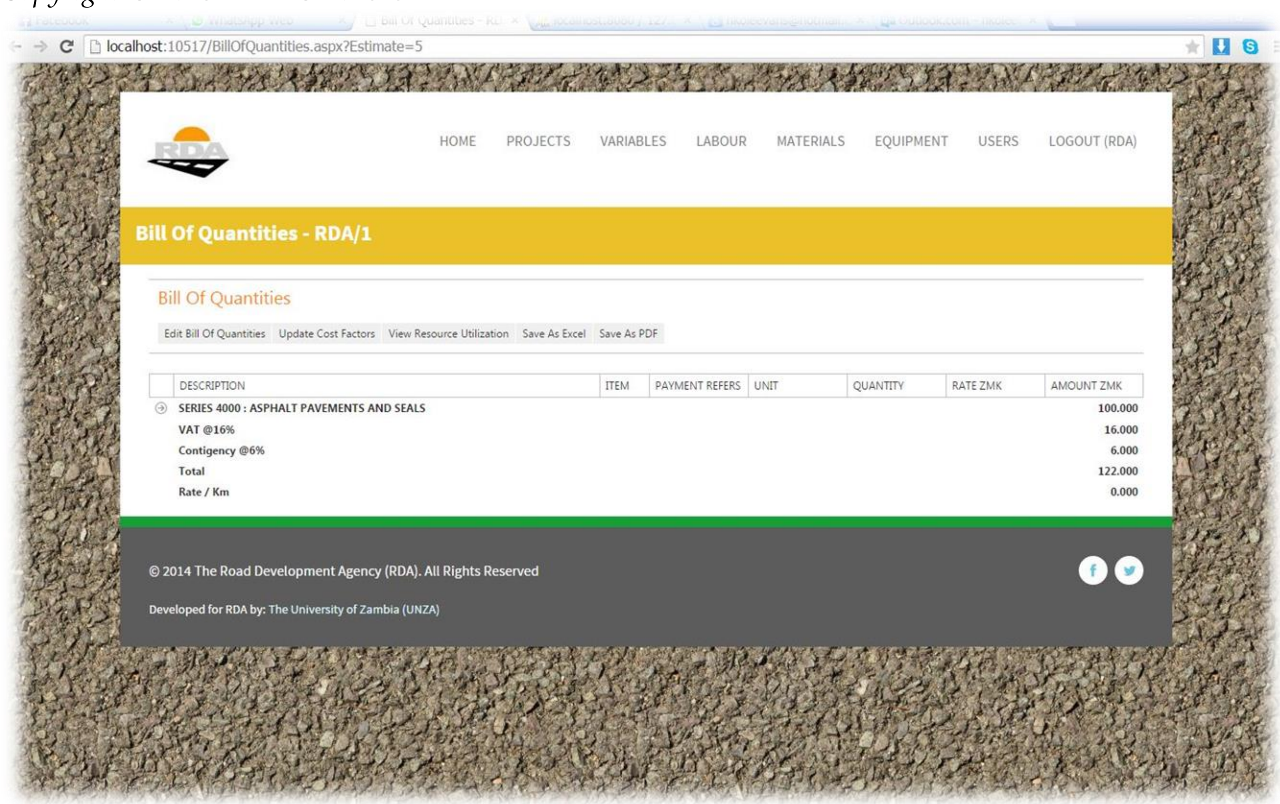
Appendix H: Quick start guide

Road Development Agency (RDA) Model for Unit Cost Estimation in the Construction of Roads through Research and Development

User Manual

Version 1.0

May 2015



Designed and developed by **The University of Zambia (UNZA)**

User Manual Contents

1. Overview

The model can be accessed at the address http://unit-cost-estimation.com during development.

Once handed over, the model will be accessible from RDA at a different address. This is dependent on how the model is set up at RDA. Please contact your ICT department for more details on this. They should be able to provide you with an IP address you can use to access the Model.

You can access the model from a browser of your choice i.e. Internet Explorer, Firefox, etc. including your mobile phone.

The Model has a streamlined layout and appearance and does not include unnecessary images, flash animations.

Technical Specifications

The model is developed with **C#** 5.0 (2012) programming language using **.NET Framework** 4.0 and **MySQL** 5 as the database engine.

The model is a 64-bit ASP.NET application which will require an Internet Information Services (IIS) webserver with ASP.4.0 and .NET Framework 4.0 or later.

The database engine is MySQL 5. Thus the model will also require a MySQL Server to host its database. The webserver and MySQL server should be able to communicate with each other.

The front end is **HTML 5**, **CSS 3**, and **JavaScript**. The model also uses a lot of popular web technologies and frameworks such JQuery, Bootstrap, etc.

To improve on performance and loading times, the Model makes heavy use of AJAX. AJAX allows certain parts of a website to update without refreshing the entire page. You can see this behaviour when expanding and collapsing items on Bill of Quantities.

This has implications on the type of browsers you use to access the model. The model will not run very well in very old browsers and will require features such as JavaScript enabled.2.

Accessing & using the Model

To access the model, go to the IP Address provided to you by your ICT personnel or systems administrator using your browser. This will be a number as **192.168.3.120:8080** or a name such as **rdamodel.rda.org.zm**.

You will need to provide a password and username to proceed.

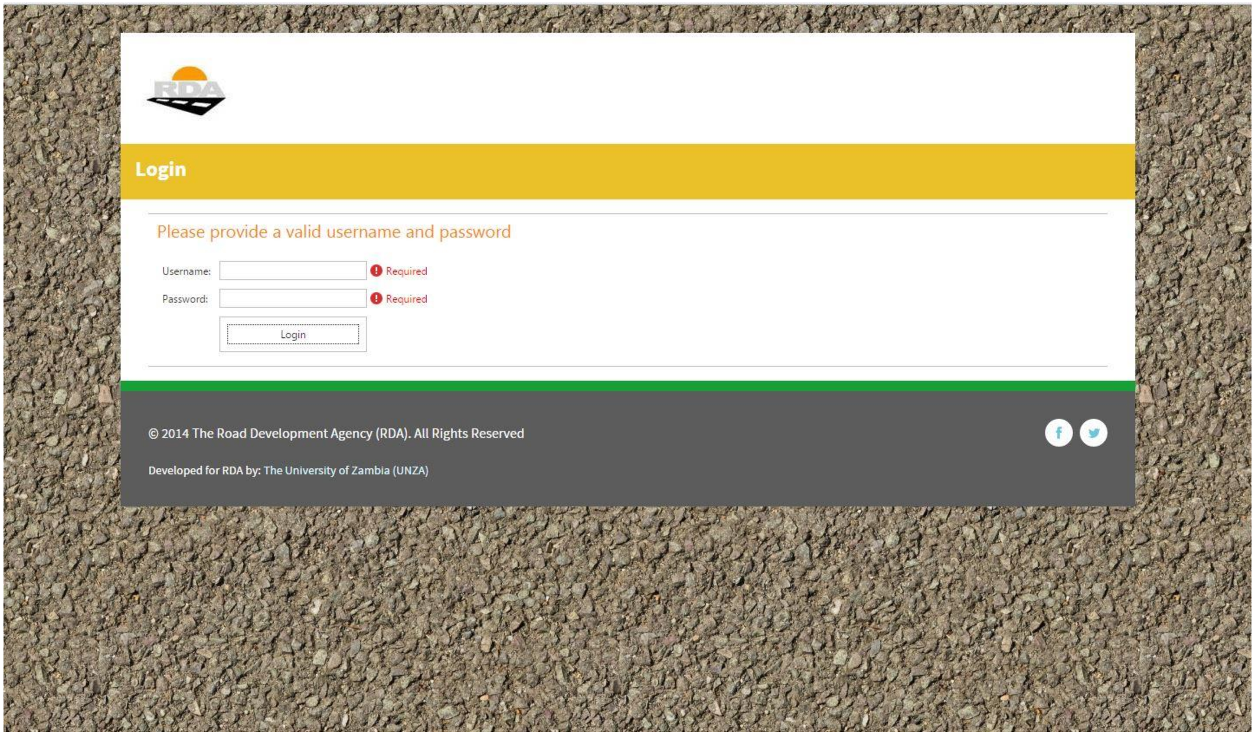


Fig 2.1 Login Screen

You can access the Model from any location in RDA as long as you are connected to the Local Area Network (LAN) or Wide Area Network (WAN) for RDA. This also includes other provinces and regions outside Lusaka. Your ICT department will have Firewalls and other security software running, please contact them if you have difficulties accessing the model despite being connected to the network.

You will need to provide a password and username.

If your ICT department has VPN setup, you can also access the model from any location including outside Zambia as long as you have Internet.

You can access the Model from your tablet or mobile phone. The Model is optimized to display correctly in each of these devices.

Start Page

The default page is shown in **Fig 2.2.** This is the default page of the Model.

The start page shows a greeting and some quick actions you can take to get started

You can access the start page at any time by clicking **HOME**

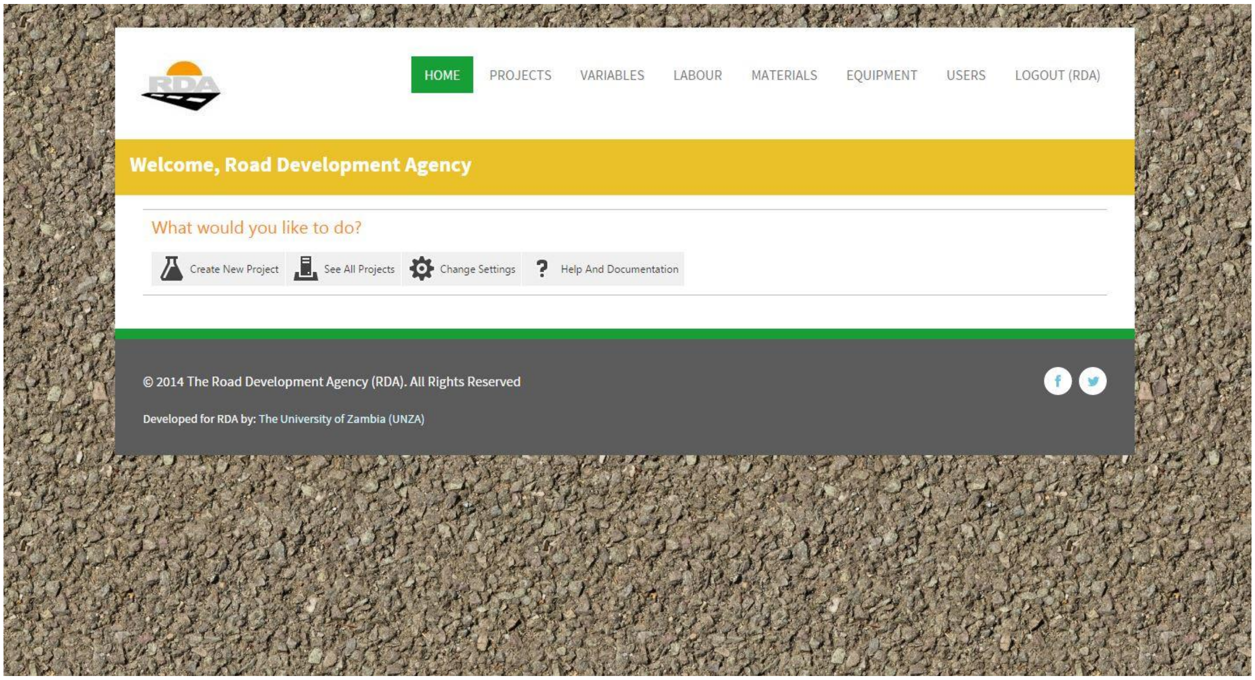


Fig 2.2 Start page

You can use the top horizontal menu to access most features on the model. These include materials, equipment, Variables etc.

The menus and options you see in the model will differ depending on your user account. Your systems administrator may for example have access to additional features and menus which are not accessible to you.

3. Adding units, materials, currencies, equipment, workers and labour information

Units

To add or update units, you must go to **Materials** > **Units**. **See Fig 3.1**.

To update an existing unit, simply select it and click **Update**.

To add a new unit, click **New**.

Adding and updating units

See **Fig. 3.2**.

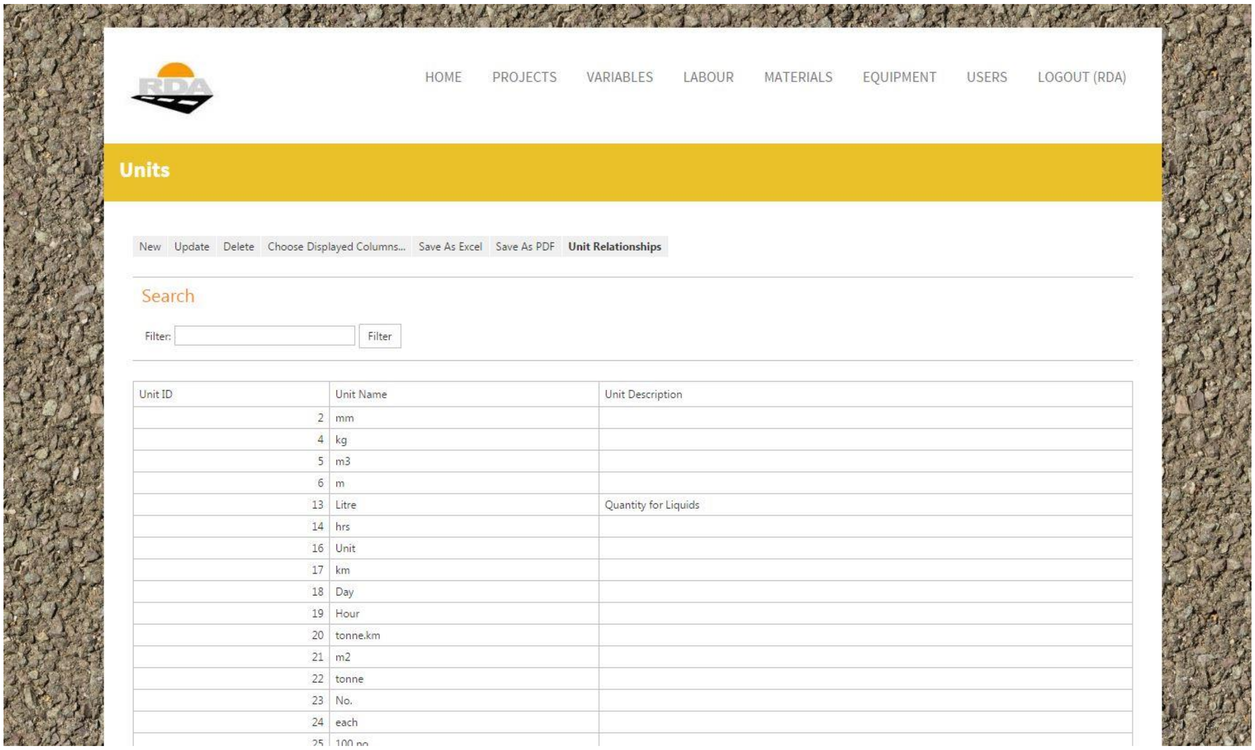


Fig 3.1 Units

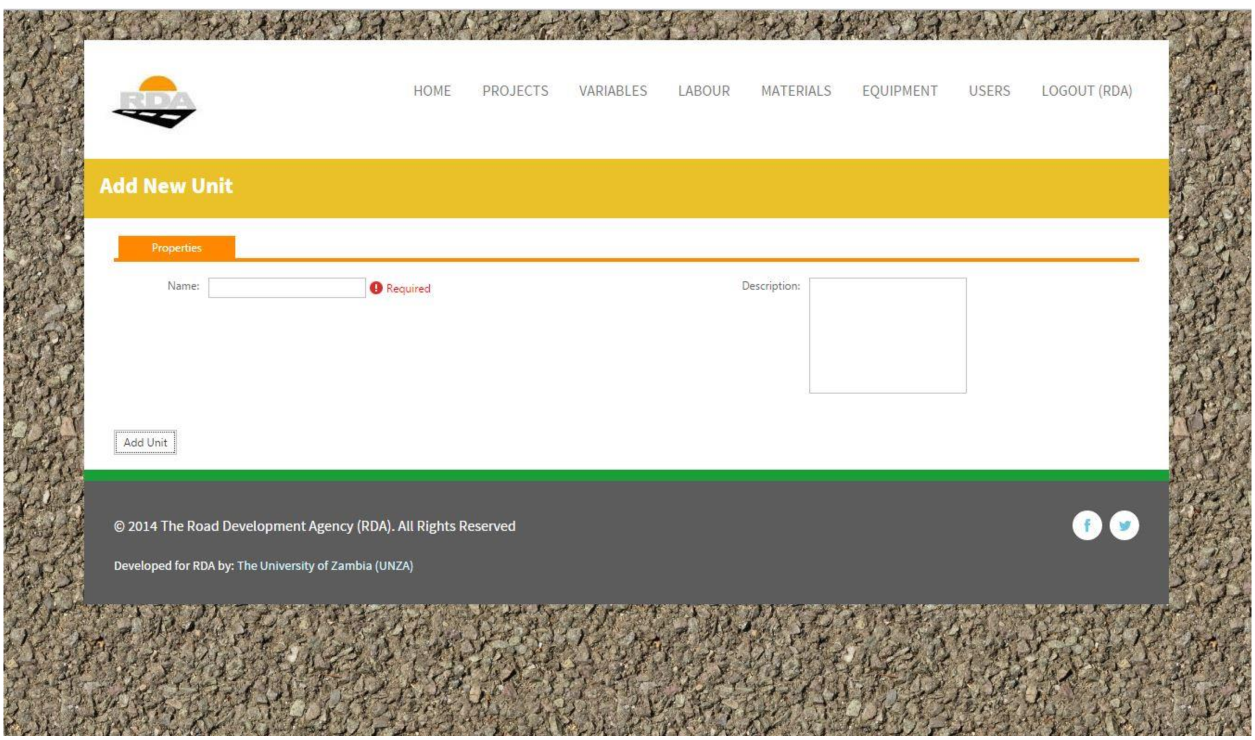


Fig 3.2 Updating and adding units

Simply provide a name for the unit and click **Add Unit.**

If you are instead updating a unit, click **Update**.

The name for a unit is mandatory. You will need to provide a name before you can save the unit.

Materials

To add or update materials, go to Materials. **See Fig 3.3**.

To update an existing material, simply select it and click **Update**.

To add a new material, click **New**. To add currencies click **Currencies**

To add regional prices, click **Add Regional Price**, to see regional prices, click **Regional Prices**.

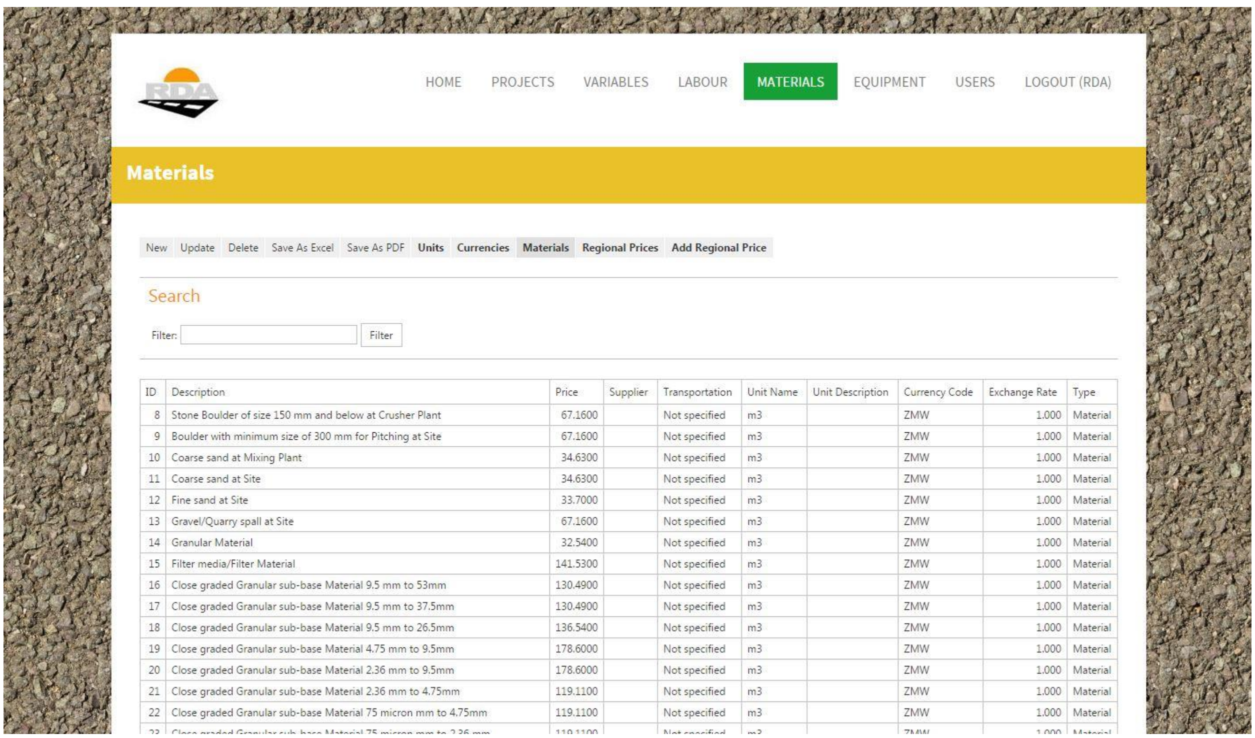


Fig 3.3 Materials

Adding and updating materials

See **Fig 3.4**. You need to provide details for the Material. When done click **Add Material**.

If you are instead updating a Material, click **Update**.

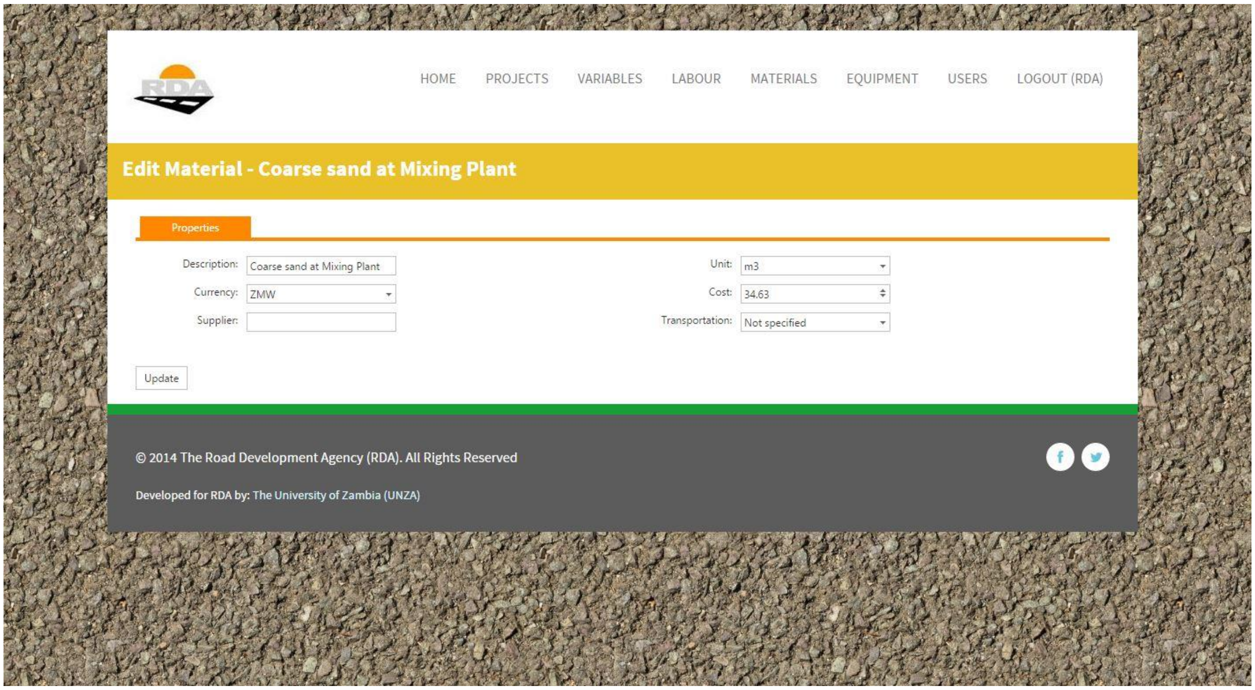


Fig 3.4 Adding and updating Materials

The description, unit, currency and transportation fields for a material are mandatory. You will need to provide them before you can save the material

Currency and Exchange Rates

To update exchange rates such as the rate of the US Dollar to the Zambian Kwacha, you must go to currencies.

The model by default performs calculations in the "local" Currency. The local currency is the currency of the location where the model is being used which in this case will be the Zambian Kwacha (ZMW).

The local currency is the currency which has an exchange rate of 1. If the model finds any monetary value without a currency defined, it assumes it to be the local currency and therefore does not perform any conversions.

For this reason you must always define a currency with an exchange rate of 1 so that all local prices should have this currency. This helps you see which materials and prices are in other currencies such as US Dollars, Zambian Kwacha, Rand, etc.

Currencies

To add or update currencies, go to Materials then click **Currencies**. See **Fig 3.5**.

To update an existing currency, simply select it and click **Update**.

To add a new currency, click **New**.

Adding and updating Currencies

See **Fig 3.6**. You need to provide details for the Currency. When done click **Add Currency**.

If you are instead updating a Currency, click **Update**.

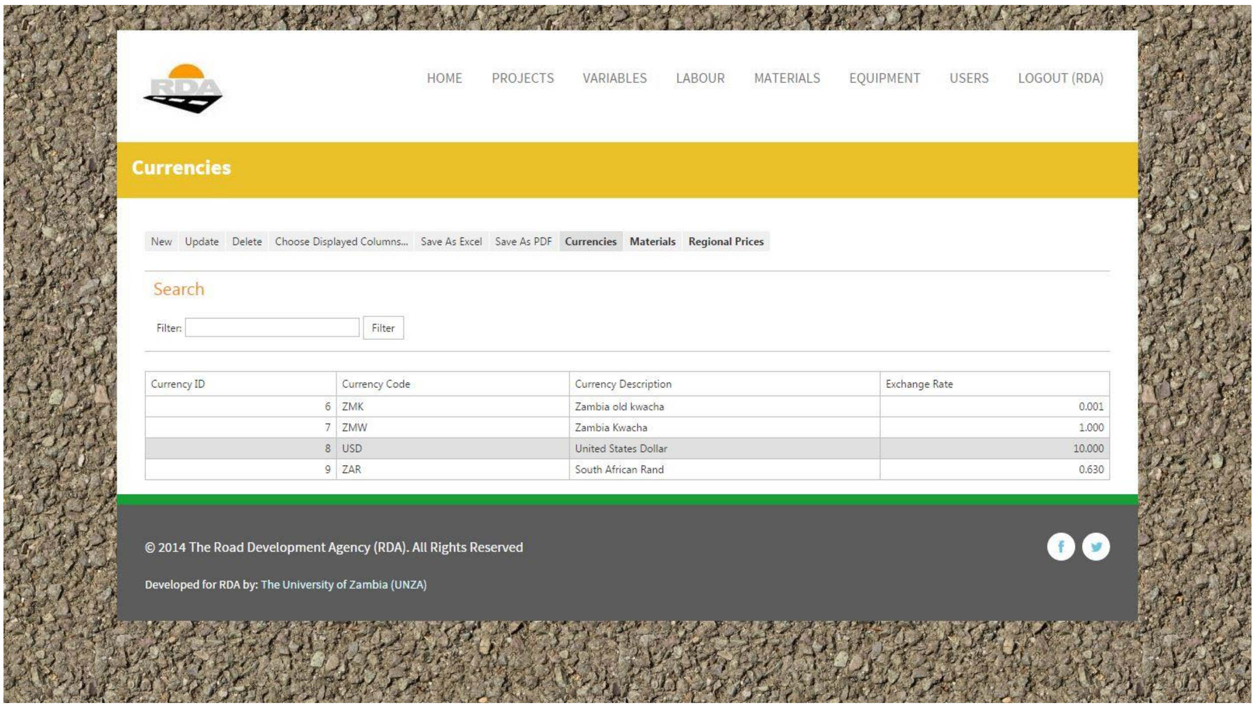


Fig 3.5 Currencies

Simply provide the code for the currency and click **Add Currency.**

If you are instead updating a currency, click **Update**.

The code for a currency is mandatory. You will need to provide a code before you can save the currency.

Suppose 1 USD = 20 ZMW, the **current exchange rate** should be entered as 20 so that all dollar amounts will be multiplied by 20 to get the Kwacha amount.

To prevent the model from being dependent on Internet, the model does not use any online service to retrieve current exchange rates. You will need to update exchange rates manually.

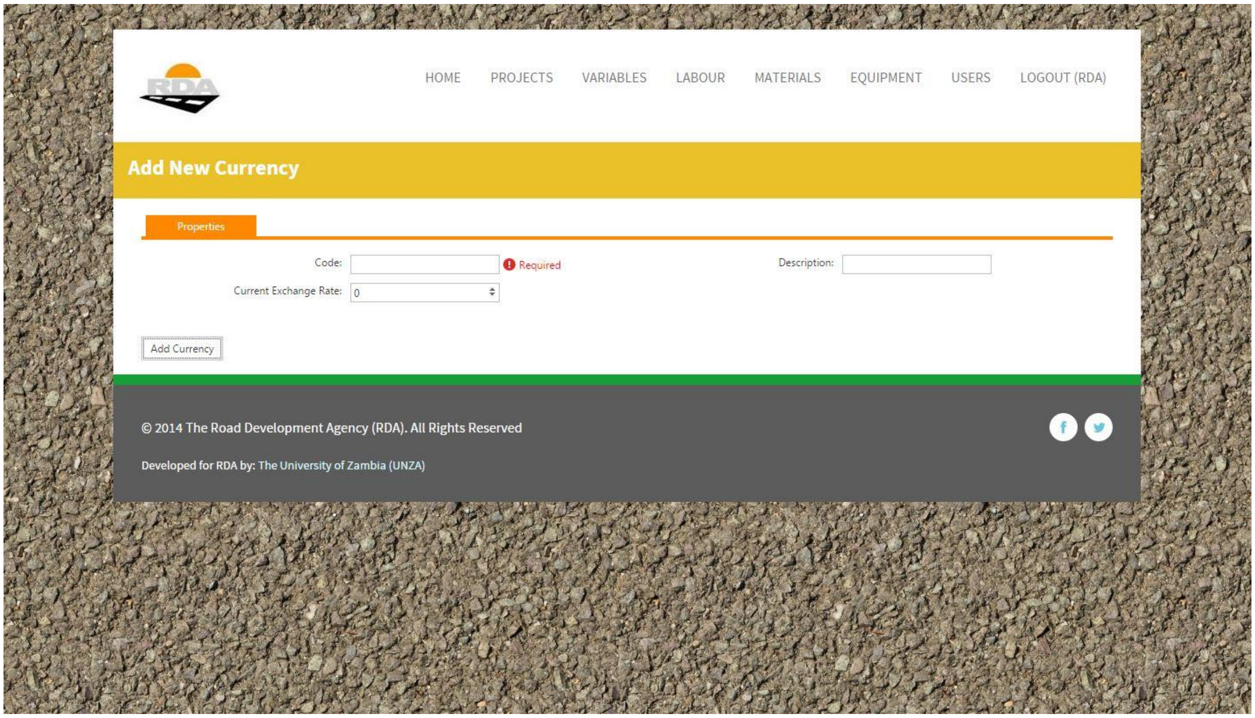


Fig 3.6 Adding and updating Currencies

Regional Prices

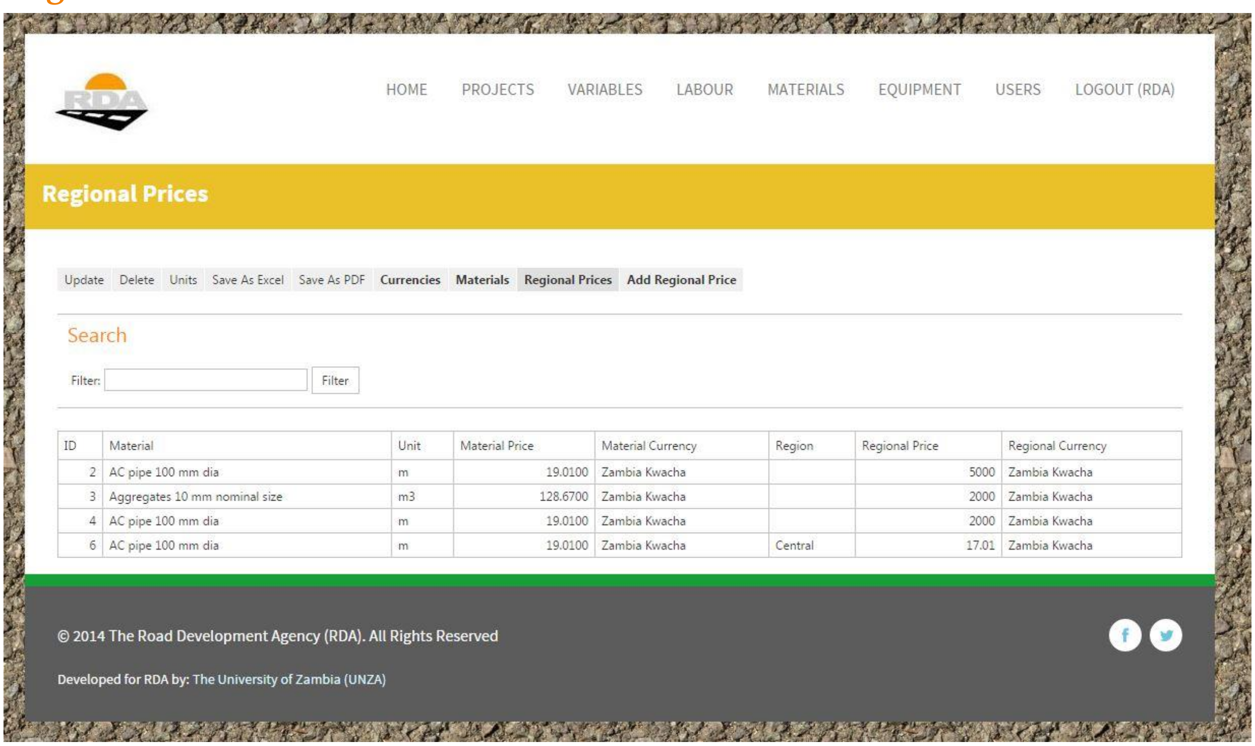


Fig 3.7 Regional Prices

Some prices for materials may be different depending on region.

You can set prices for a material for each region.

To add or remove a regional price, click **Add Regional Price**.

The model will use the material price and currency for the region if the price for the material has been set in that region, if not, it will use the global price and currency for the material.

Please note that some user accounts may not have enough rights to set regional prices.

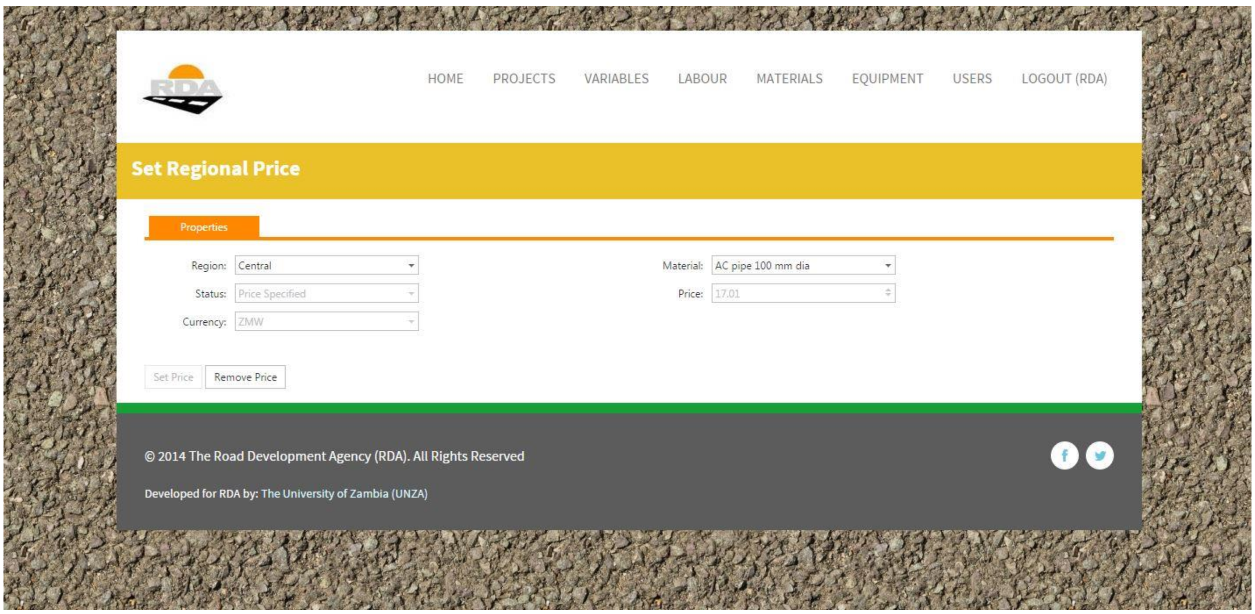


Fig 3.8 Setting and Removing Regional Prices

First select the region and material.

You will be able to remove or update the price if it's set for that material and region.

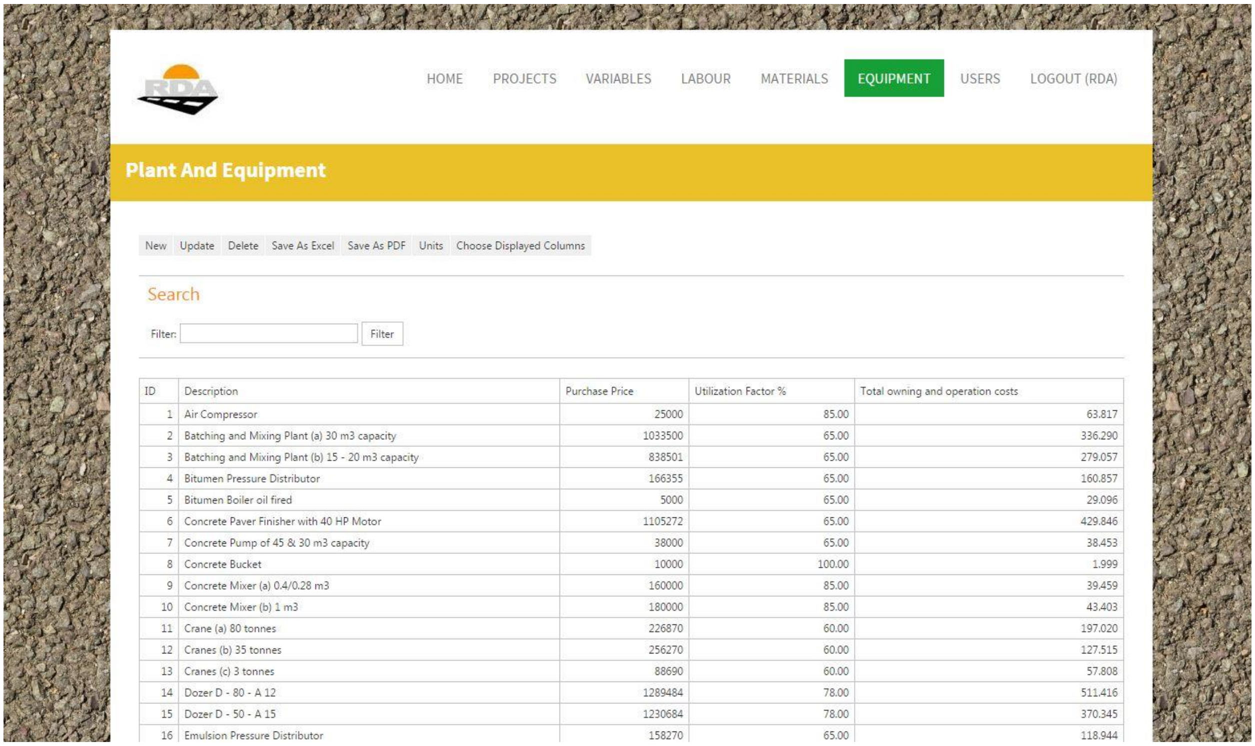
If no price is set for the selected material and region, you will be able to add one

Equipment

To add or update equipment, go to **Equipment**. See **Fig 3.9**.

To update existing equipment, simply select it and click **Update**.

To add new Equipment, click **New**.



ID	Description	Purchase Price	Utilization Factor %	Total owning and operation costs
1	Air Compressor	25000	85.00	63.817
2	Batching and Mixing Plant (a) 30 m3 capacity	1033500	65.00	336.290
3	Batching and Mixing Plant (b) 15 - 20 m3 capacity	838501	65.00	279.057
4	Bitumen Pressure Distributor	166355	65.00	160.857
5	Bitumen Boiler oil fired	5000	65.00	29.096
6	Concrete Paver Finisher with 40 HP Motor	1105272	65.00	429.846
7	Concrete Pump of 45 & 30 m3 capacity	38000	65.00	38.453
8	Concrete Bucket	10000	100.00	1.999
9	Concrete Mixer (a) 0.4/0.28 m3	160000	85.00	39.459
10	Concrete Mixer (b) 1 m3	180000	85.00	43.403
11	Crane (a) 80 tonnes	226870	60.00	197.020
12	Cranes (b) 35 tonnes	256270	60.00	127.515
13	Cranes (c) 3 tonnes	88690	60.00	57.808
14	Dozer D - 80 - A 12	1289484	78.00	511.416
15	Dozer D - 50 - A 15	1230684	78.00	370.345
16	Emulsion Pressure Distributor	158270	65.00	118.944

Fig 3.9 Equipment

Adding and updating equipment

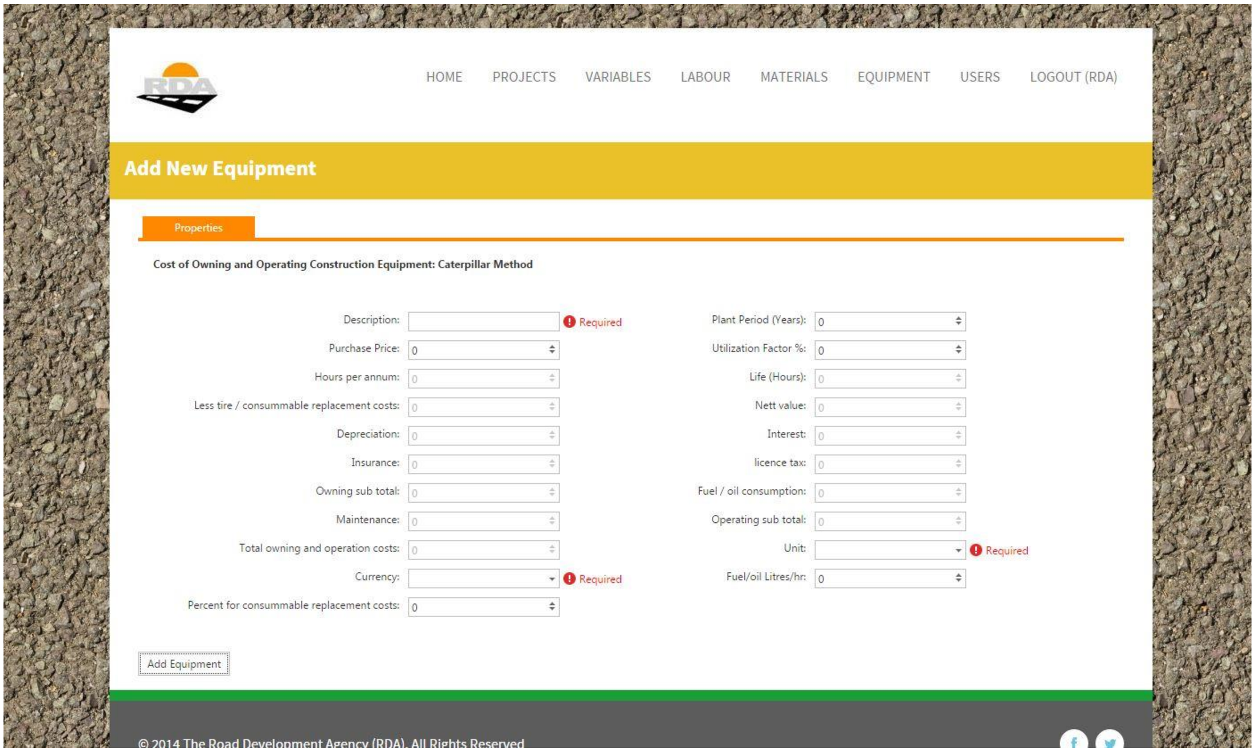


Fig 3.10 Adding and updating equipment

You need to provide a Description, Unit and Currency for the Equipment. When done click **Add Equipment**.

If you are instead updating Equipment, click **Update**.

The description, unit and currency for equipment are mandatory. You will need to provide them before you can save the equipment.

Equipment has a lot of fields however you don't need to provide all of them. You just need to provide purchase price, plant years, and utilization factor. The other fields are automatically calculated from these. You cannot enter values for these.

Construction Workers and Variables

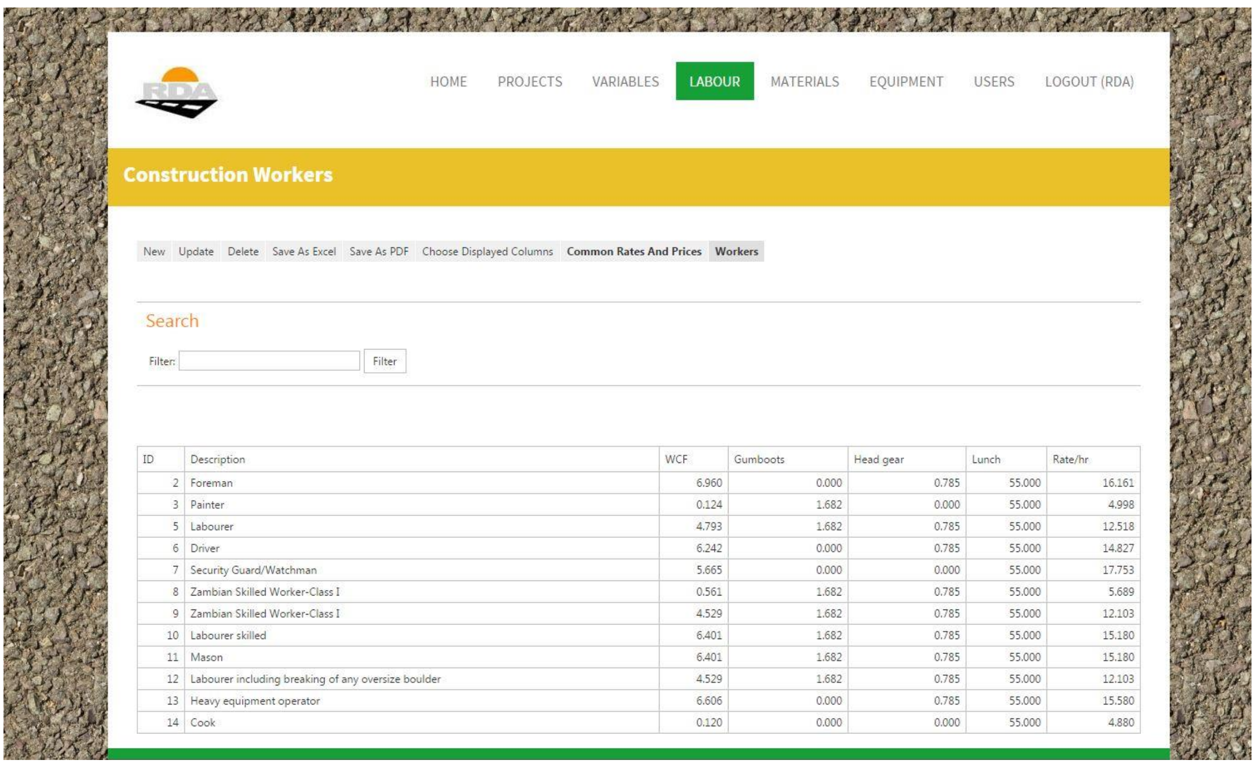


Fig 3.11 Construction Workers

To add or update workers and labour information, go to **Labour**.

To add a new worker, click **New**.

To update variables such as working hours per day, click **Variables**

Adding and updating workers

You need to provide the title, unit, description and applicable items for the worker. When done click **Add**.

If you are instead updating a worker, click **Update**.

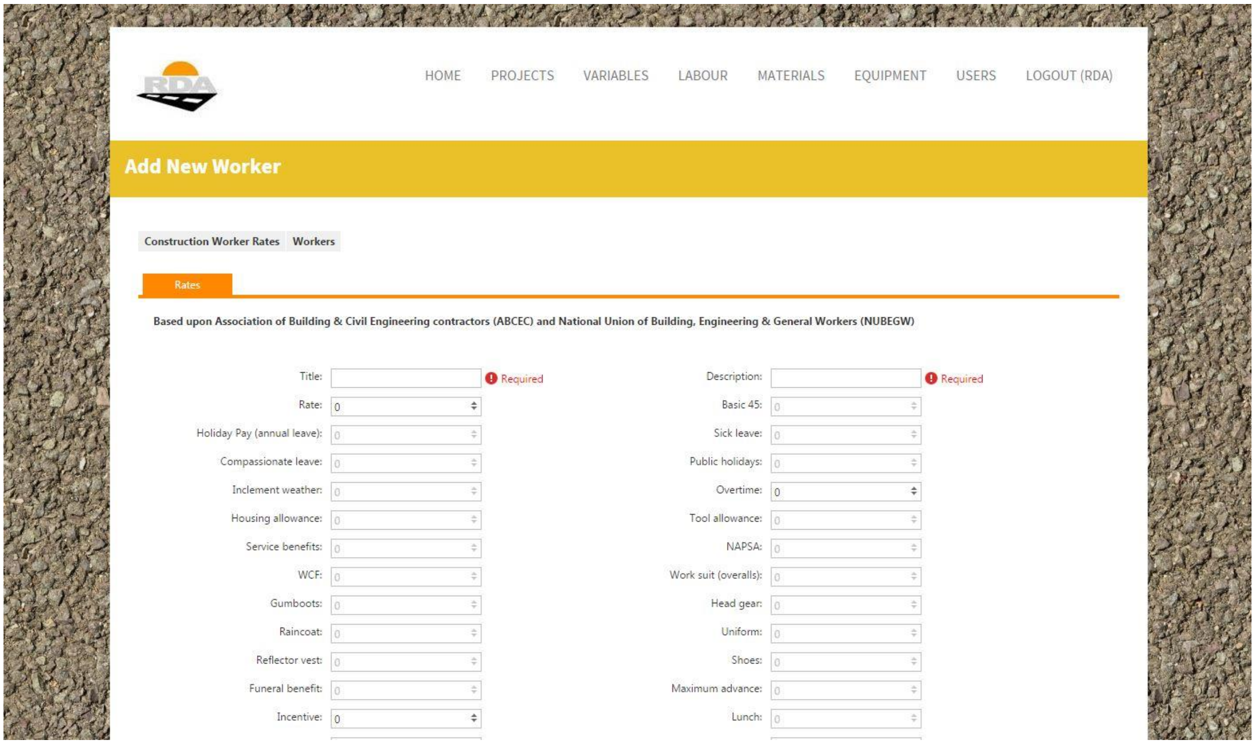


Fig 3.12 Adding and Updating Construction Workers

You will need to provide mandatory fields before you can save the worker.

Workers have a lot of fields however you don't need to provide all of them. The other fields are automatically calculated and you can't enter values for them. Applicable items specify whether to calculate items such as **work suit** for this worker. If you choose **Non Applicable**, the item will be set to zero for this worker.

Choosing the **Applicable** option means that Gumboots will be calculated for this worker. Thus this feature allows you to select what items apply to certain workers since not all workers will be entitled to items like Gumboots.

Variables

To variables such as **working hours per day**, simply change the value and click **Update**.

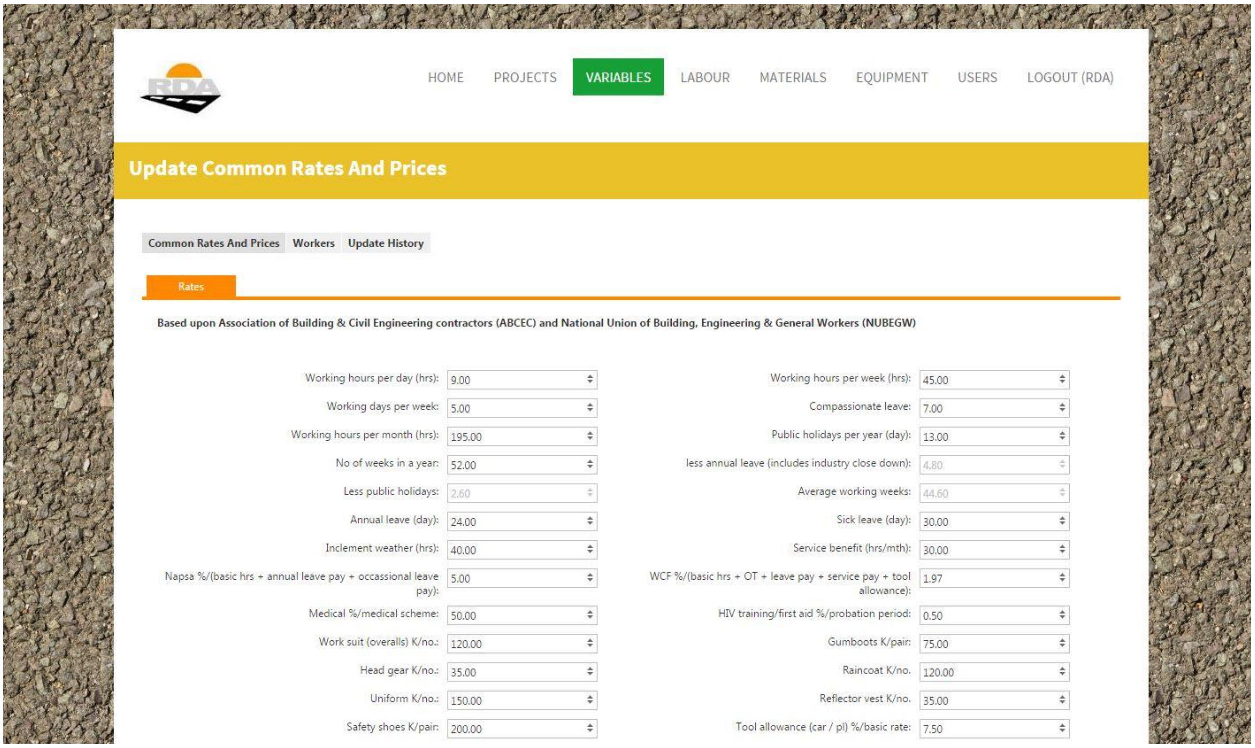


Fig 3.13 Updating Variables

There are no mandatory fields for labour information.

Some fields like **Average working weeks** are automatically calculated and you cannot enter values for them.

You will be prompted by the model after clicking Update for confirmation. Accept to update variables.

Variable changes are logged for security purposes. Administrators will be able to see that you made changes on this particular date.

The variables used here are used by Materials and Equipment rates, the model will update Materials and Equipment rates whenever you change a variable here.

4. Projects

To add or update projects, go to **Projects**.

See **Fig 4.1**.

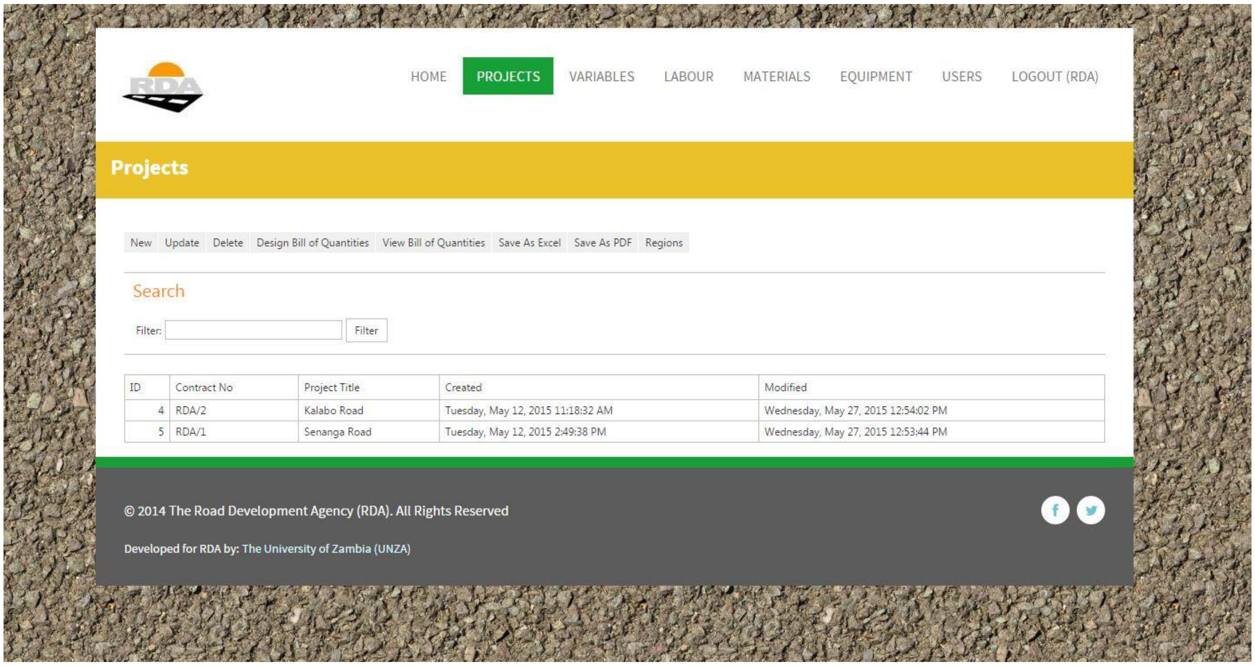


Fig 4.1 Projects

To update an existing project, simply select it and click **Update**.

To add a new project, click **New**.

To design the bill of quantities for this project click **Design Bill of Quantities**

To view the bill of quantities for this project click **View Bill of Quantities**

Depending on your user account, you may only see projects that belong to you or your region.

Adding and updating projects

Simply provide a name for the project and click **Add Project.**

If you are instead updating a project, click **Update**.

See **Fig 4.2**.

The **Contract No.** for a project is mandatory. You will need to provide a **Contract No.** before you can save the project.

You also need to specify the Free Haul distance and Cost Factors such as **Contractor Capacity**. Cost Factors are used by Neural Networks when calculating rates.

For more information about Cost Factors, rest your mouse on a factor such as **Political Environment** and you will see a description about the meaning of that factor.

If you do not wish to have neural networks in your project, make sure **Enable Neural Networks** is set to No.

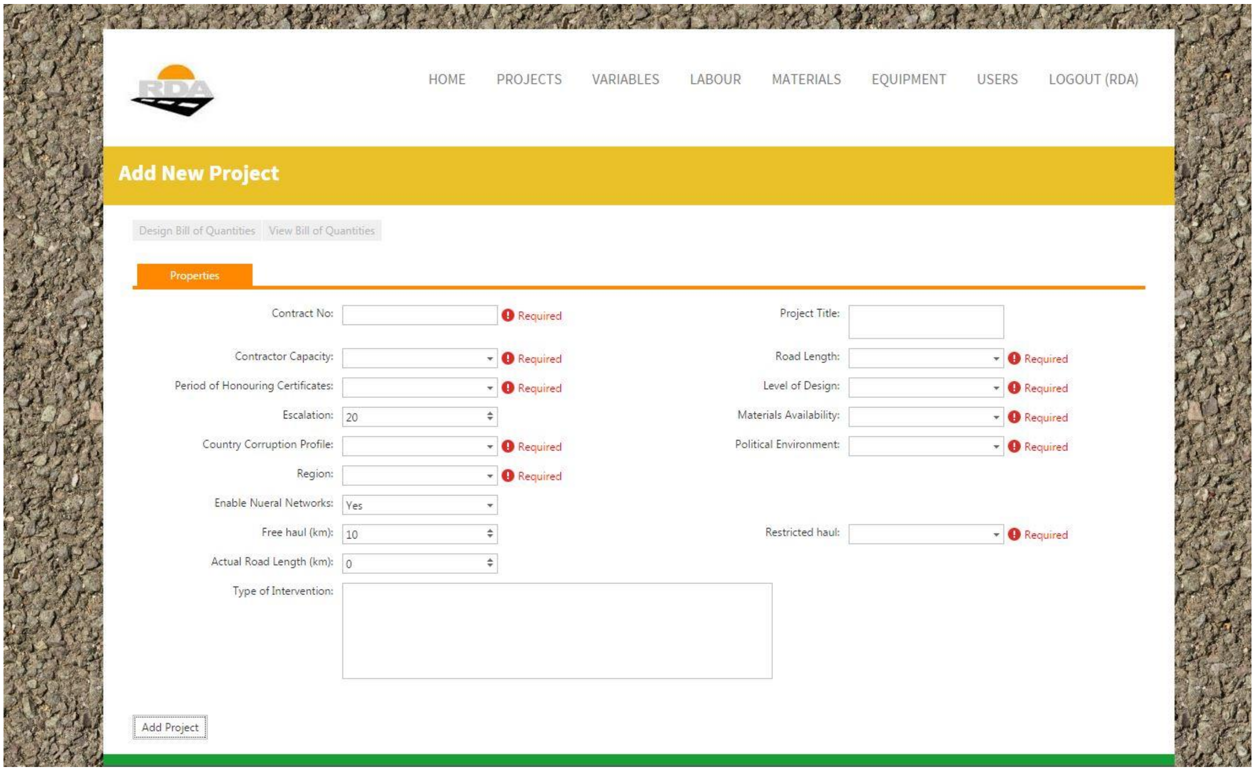


Fig 4.2 Adding and Updating Projects

Designing a bill of quantities

When you create a new project, it has access to all the series as defined in the SATCC pay items. Designing a bill of quantities is simply a matter of providing quantities for pay items you have in your project.

See Fig 4.3.

To design a bill of quantities for a project, click **Design Bill of Quantities** when you are at the page shown in Fig 4.2. If you are at the projects screen, make sure you select the project first.

If you have already designed a Bill of Quantities, you can click **View Bill of Quantities** to view a Bill of Quantities.

To design a Bill of Quantities, navigate by expanding to the pay items you want such as **(Red lines (broken or unbroken) 100mm wide),** click on **Edit** and specify quantities. Click **Update** to save. Once you specify a quantity other than zero, this item will appear in your Bill of Quantities.

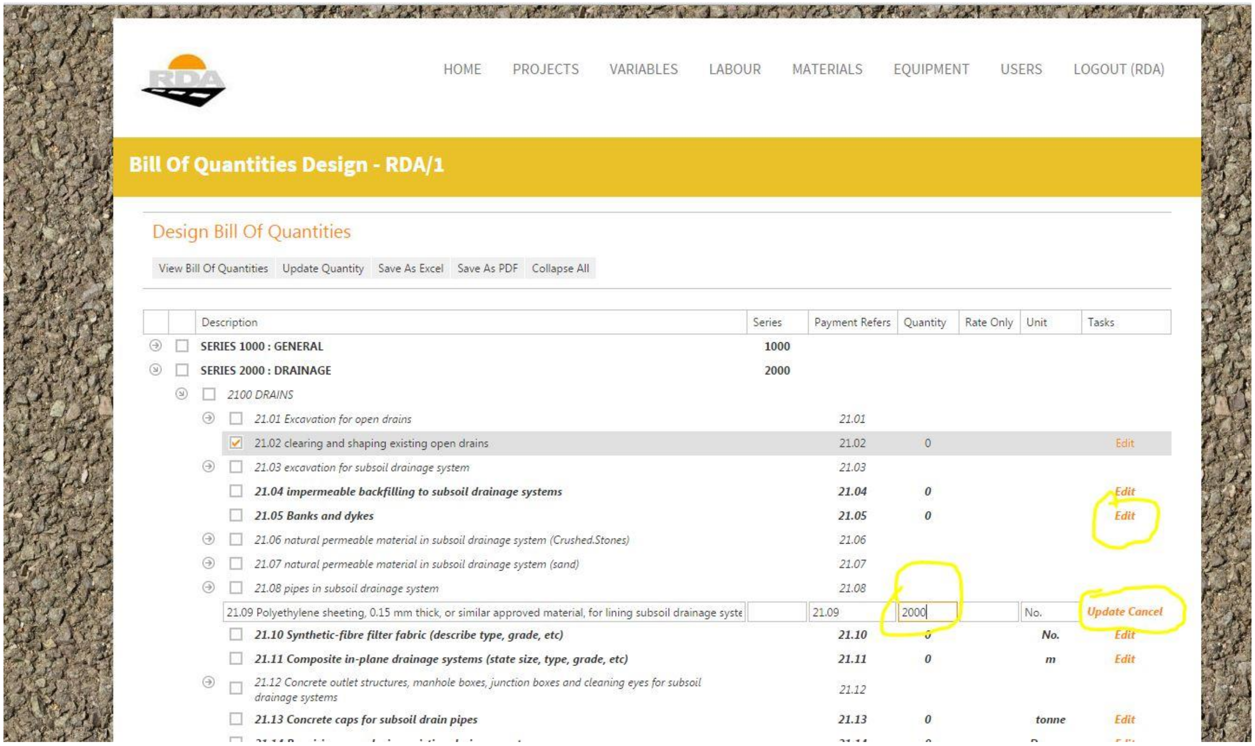


Fig 4.2 Designing a Bill of Quantities

Rate Only and PC Sum

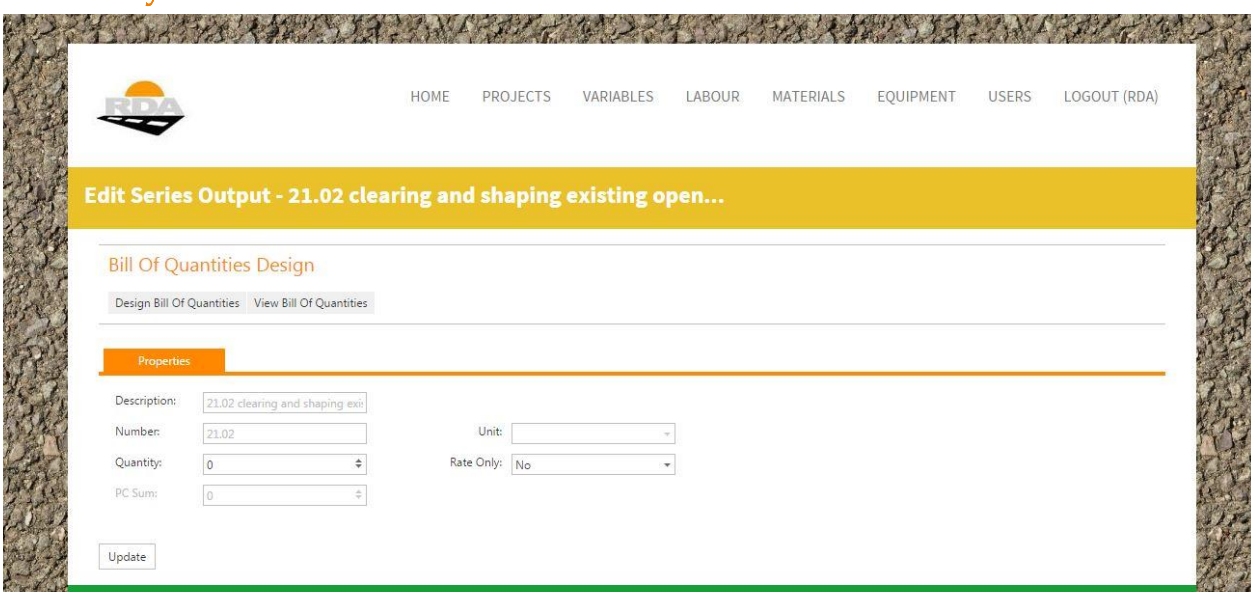


Fig 4.3 PC Sum and Rate Only

To make this item a **Rate Only** item so that it appears on the Bill of Quantities without a quantity, select it and click **Update Quantity** above. In the resulting screen, set **Rate Only** to Yes. This item will be zero but will display on the Bill of Quantities.

If this item is a lamp sum, you will be able to specify the lump sum amount as well. Only pay items that have been defined as lump sum will allow you to specify a lump sum here.

Viewing a bill of quantities

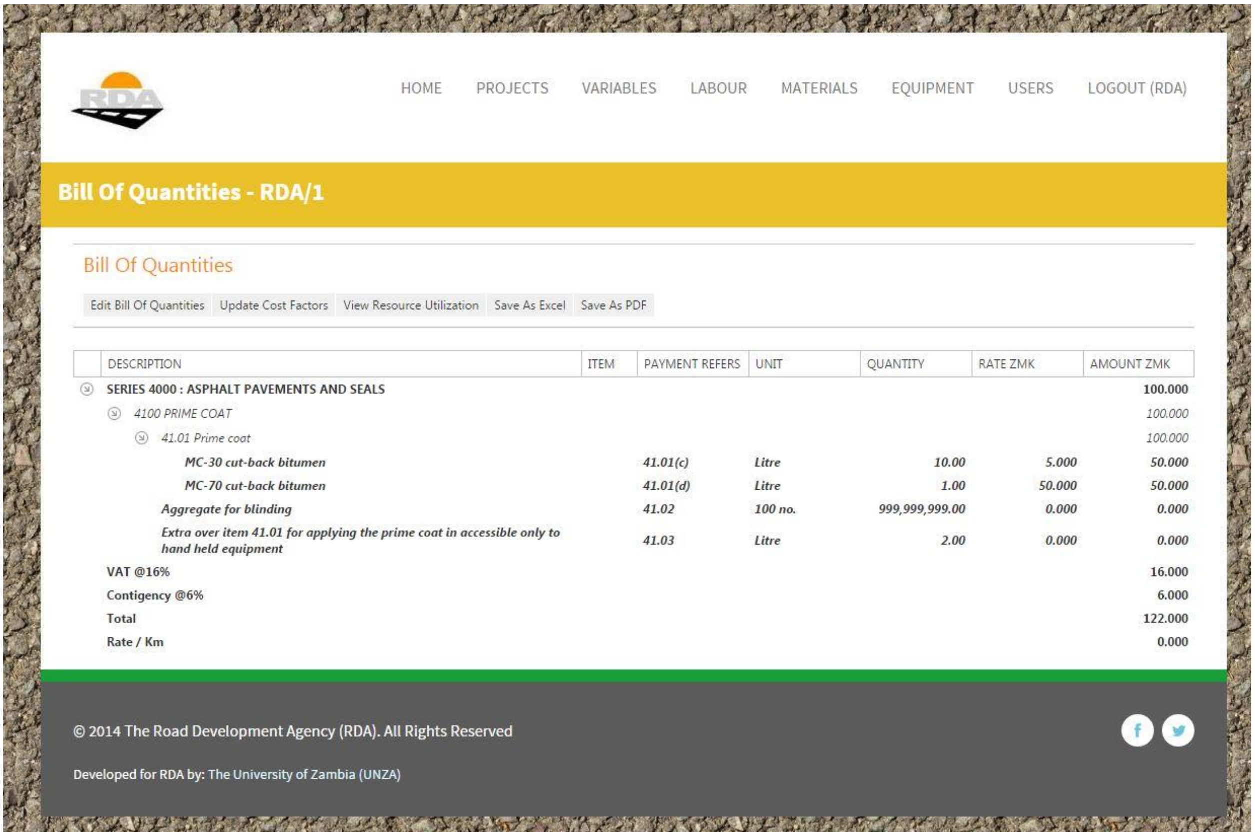


Fig 4.4 Viewing a Bill of Quantities

To view a bill of quantities for a project, click **View Bill of Quantities** when you are at the page shown in Fig 4.2. If you are at the projects screen, make sure you select the project first.

If you have already designed a Bill of Quantities, you can click **View Bill of Quantities** to view a Bill of Quantities.

A Bill of quantities is interactive.

You can drill down by expanding an item so that you see totals for individual series, categories and pay items.

You can export the Bill of Quantities to Excel and other formats by simply clicking **Save As Excel.**

Resource Utilization

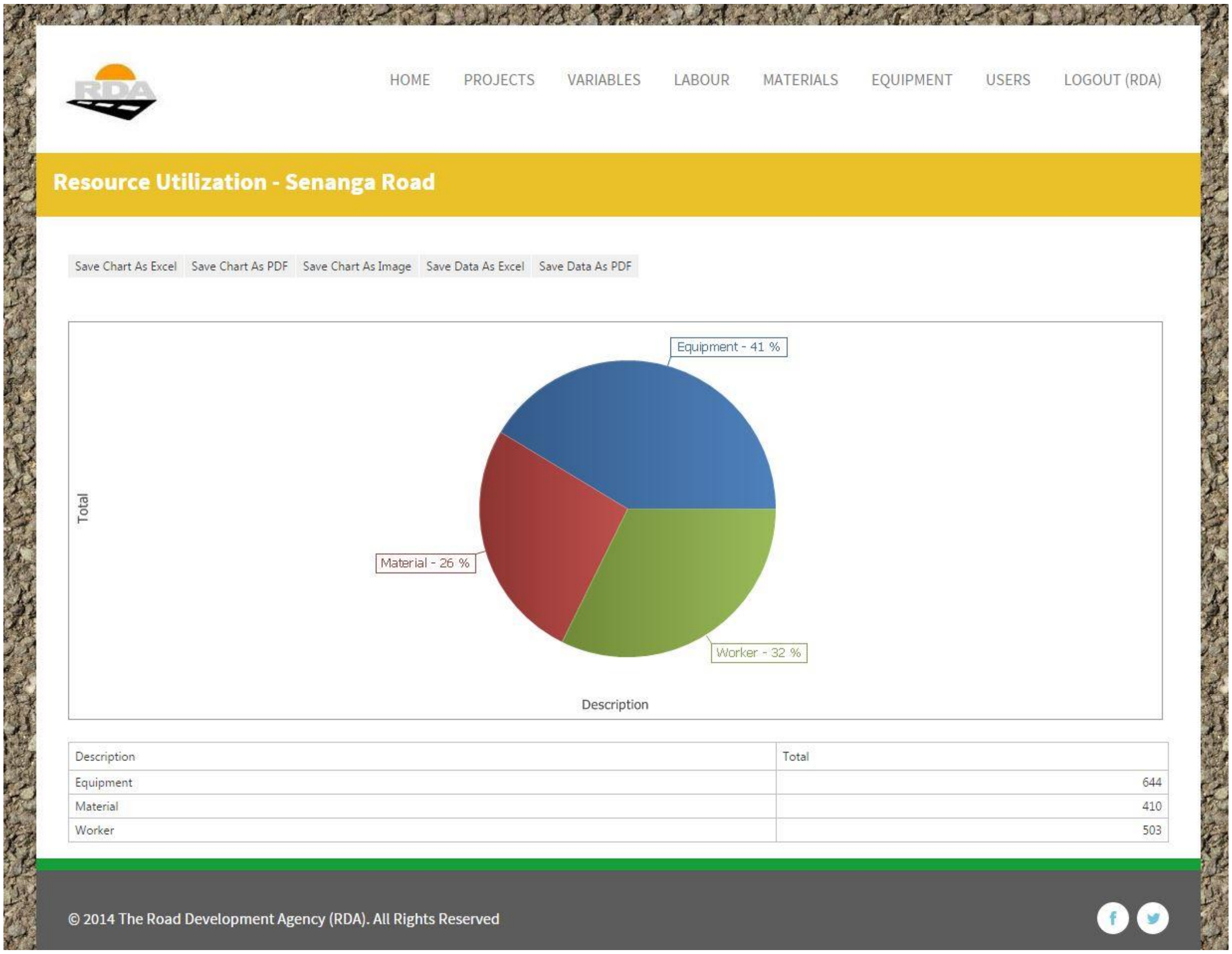


Fig 4.5 Viewing Resource Utilization

You can view Resource Utilization by clicking **View Resource Utilization**. This option is available when viewing a Bill of Quantities.

Conclusion

The model has built in data export and import features. On almost all screens you will see the **Save As PDF** and **Save As Excel** options. Clicking them will immediately download the selected document.

On some screens such as equipment, labour, etc. not all columns are displayed, use the **Choose Displayed Columns** option to select more columns

Please don’t hesitate to ask for help and clarification concerning the model, its features or this user manual.

User Manual prepared by Nkole Evans

(nkoleevans@hotmail.com).

Appendix I: International data collection - structured questions

DATA COLLECTION INSTRUMENT FROM SADC COUNTRIES

A. GENERAL INFORMATION

1. Country: ....

2. Name of Institution: ....

3. Summary of country's road sector

    i. Total road network (km)
    ii. Paved network (km)
    iii. Unpaved (km)
    iv. Approximate total annual road project costs in US$
    v. Approximate number of contractors in road sector
    vi. Categories of contractors (grades or classification system)
    vii. Ratio of large contractor type (foreign / local)

B. COST ESTIMATION

4. Do you produce Engineers estimates for projects? (Yes / No)

5. If yes how does your organisation come up with engineers estimate?

    - ☐ First principle (build up rate manually)
    - ☐ Historical (use rates from previous tenders with some adjustment factor)
    - ☐ Computer software (please state)……………………………………
    - ☐ Own estimating experience

6. How accurate is the cost estimation model / software? (±5,10,20%)

Performance levels or output rates are standards or benchmarks for a particular sector for example a bricklayer can lay 1.06m^2 per hour

7. Does the road sector have formal or official productivity rates used to determine efficiency of the sector?

8. Which institution is the custodian of the productivity rates?

C. PLANT AND EQUIPMENT

9. Is plant and equipment required for road construction readily available in country ? (Yes/ No)

10. What is the state of construction plant and equipment in country? (Poor / Satisfactory / Good)

11. Are there enough sources of plant and equipment available in the country (Yes/No)

12. Provide approximate ratio of equipment use in the country [owned / hired (leased)]

13. Provide hourly rates of equipment on attached list.

14. Can you provide a build-up of rates for equipment?

15. What variables are used? (see attached list)

16. Indicate a company that can provide breakdown of equipment variables

……………………………………………………………………………………………….

D. LABOUR

17. Does road sector have associations for contractors? (Names)

18. Do these associations provide minimum conditions of work for their members?

19. Can you provide copy of any construction (union) work conditions agreement?

20. Provide hourly rates of different categories of construction workers on attached list

21. Can you provide a build-up of rates for labour from prescribed minimum wage?

22. What variables are used in the build-up?

E. MATERIAL

23. Provide ratio of material available (locally / imported)

24. How is the availability of road construction material in country? (Poor / Satisfactory / Good)

25. Provide prices of construction materials on attached list

F. COST FACTORS

Apart from plant, equipment, labour and material there are other factors which affect unit costs in the country road sector. Please indicate their impact on unit costs using the scale 1 to 5 where: 1= No impact, 2 = Low, 3 = moderate, 4 = high, 5 = Very high

S/No	Factor	Impact				
		1	2	3	4	5
i.	**Corruption** - extent to which corruption affects unit rates					
ii.	**Project need -** Do road projects that are not budgeted have higher unit rates than budgeted ones?					

S/No	Factor	Impact				
		1	2	3	4	5
iii.	**Payments** regime of client. Do contractors factor potential delays in payment into pricing of contracts? What's the effect on unit rates?					
iv.	**Client Type –** Does the client type whether government ministry, public institution (parastatal), private or foreign affect unit rate?					
v.	**Contract financing -** Is it easy for a contractor to obtain finance to assist with their cash flows? How does this affect unit costs					
vi.	**Project planning –** how does the client's project planning such as budget allocations, appointment of supervision consultants, quality of bidding documents, high contingency amounts affect unit rates?					
vii.	**Project Management –** How does client's capacity to supervise projects, level of variations, affect unit rates?					
viii.	**Procurement –** does the contractor selection method e.g open tendering, single sourcing affect unit rates?					
ix.	**Exchange rate** How does the exchange rate risk on the purchase of imported materials or equipment affect unit rates?					
x.	**Material shortages** – how do material shortages e.g. cement, fuel, bitumen affect unit rates?					
xi.	**Material Source** – how does the source of materials such as local or imported affect unit rates?					
xii.	Does **Contractor** competition affect unit rates in your country?					
xiii.	Does **political interference** have an effect on unit rates?					
xiv.	If **Duration** is known, how does this affect unit rates?					
xv.	**Project scope –** new construction, rehabilitation, upgrading affect unit rates?					
xvi.	**Location –** does remoteness of a project affect unit rates? (urban or rural)					
xvii.	**Topography –** does the terrain affect unit rates?					
xviii.	**Fuel –** does the price of fuel affect unit rates?					

26. From your experience, are there other cost factors not mentioned in the table above that you feel have a major impact on unit rates?
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

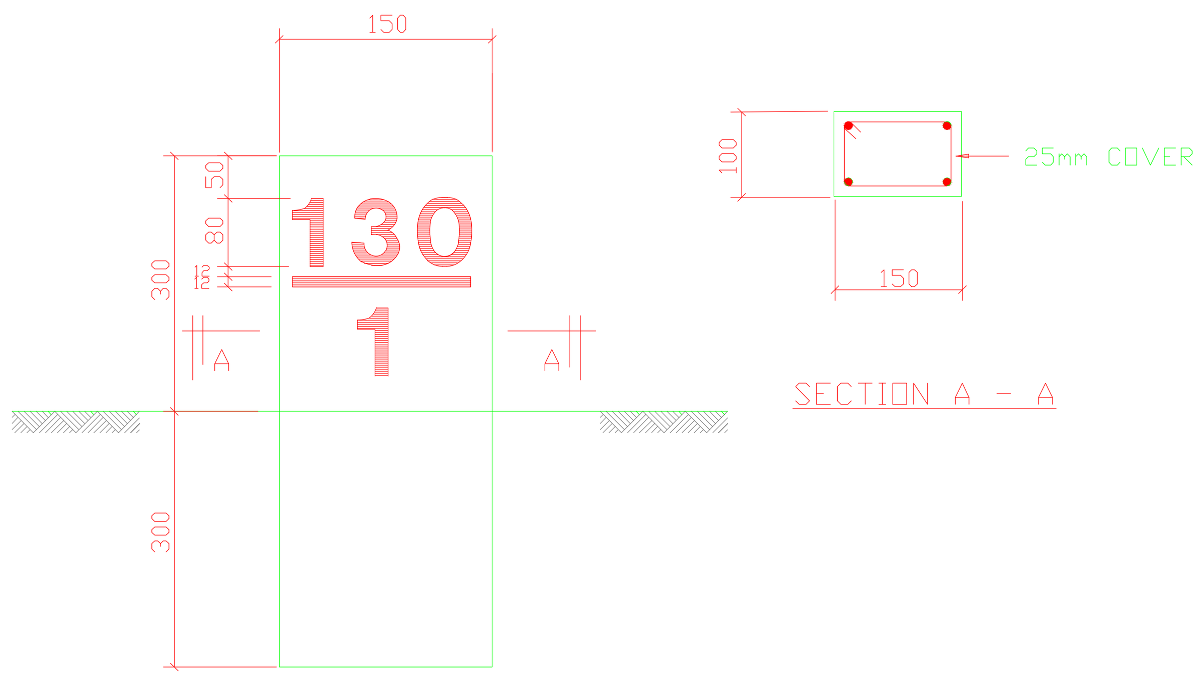
27. Please indicate average % included as overhead & profit in unit rates ………………………...

28. Please indicate current foreign exchange rate to the US$ …………………………………...

Checklist of information to be collected

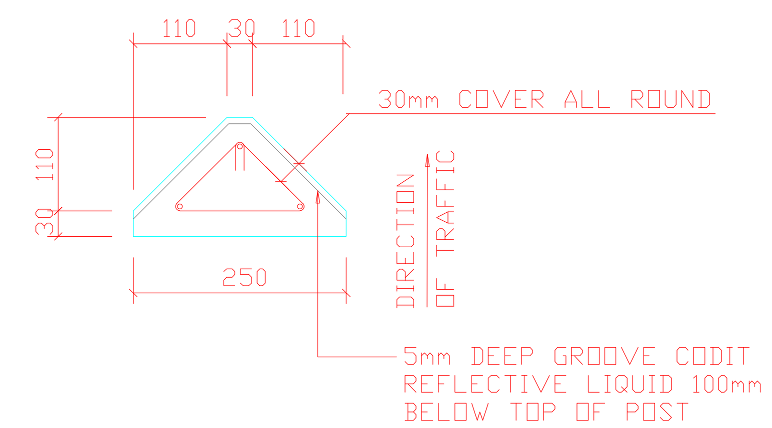
i. Five (5) priced Bills of Quantities for completed works indicating duration, location (urban / rural)
ii. Hourly rates of different categories of construction workers on attached list
iii. Prices of construction materials on attached list
iv. Build-up of rates for labour from prescribed minimum wage.
v. Variables used in the build-up of labour rates
vi. Hourly rates of equipment on attached list
vii. Build-up of rates for equipment.
viii. Variables used in build-up of hourly rates of equipment
ix. Name of company that can provide breakdown of equipment variables.

Appendix J: Road furniture drawings

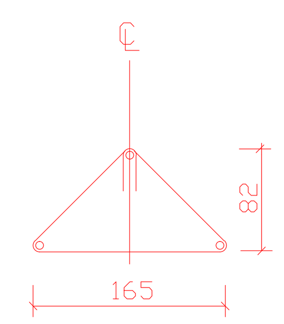


FRONT ELEVATION

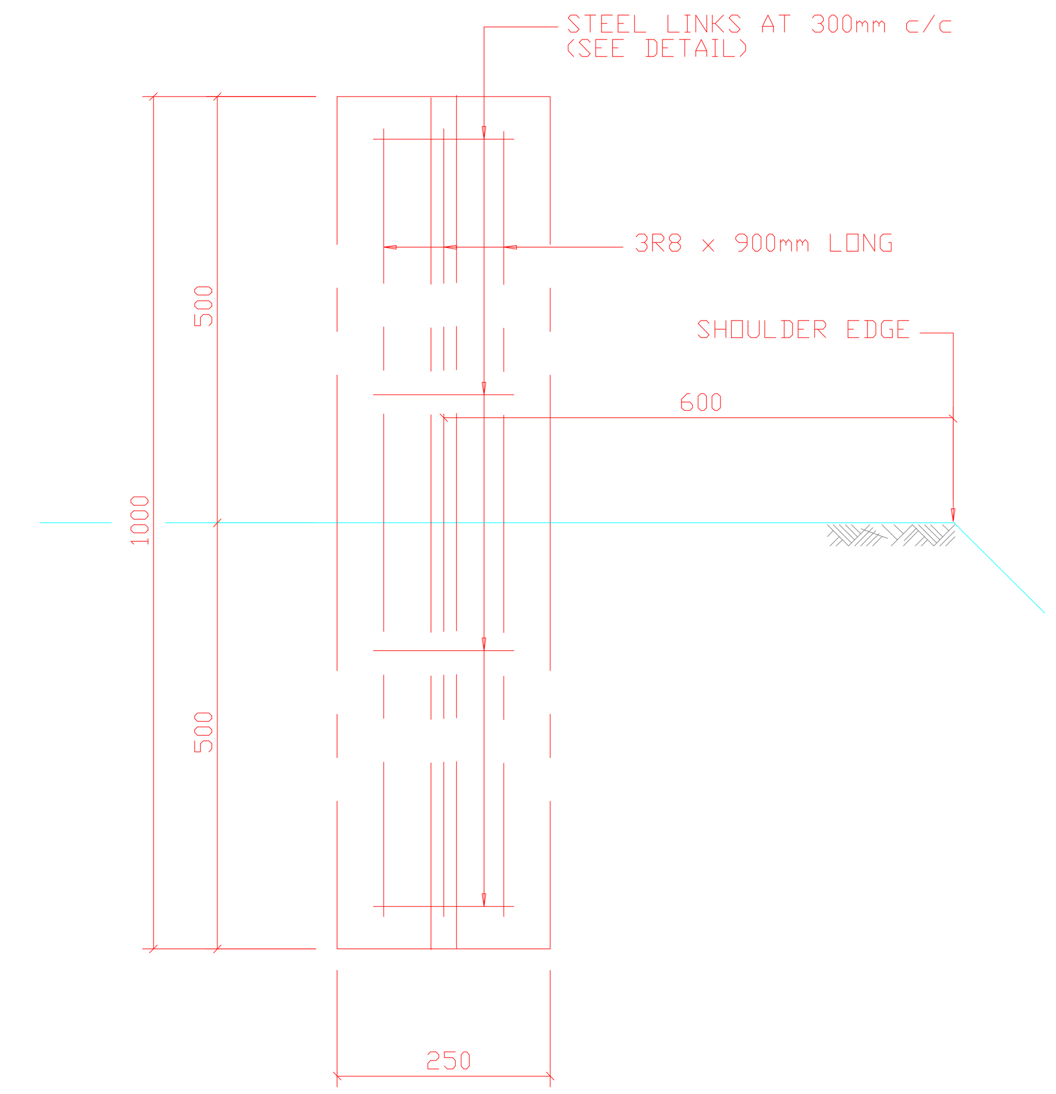
DETAIL OF CULVERT-MARKER LETTERING



PLAN

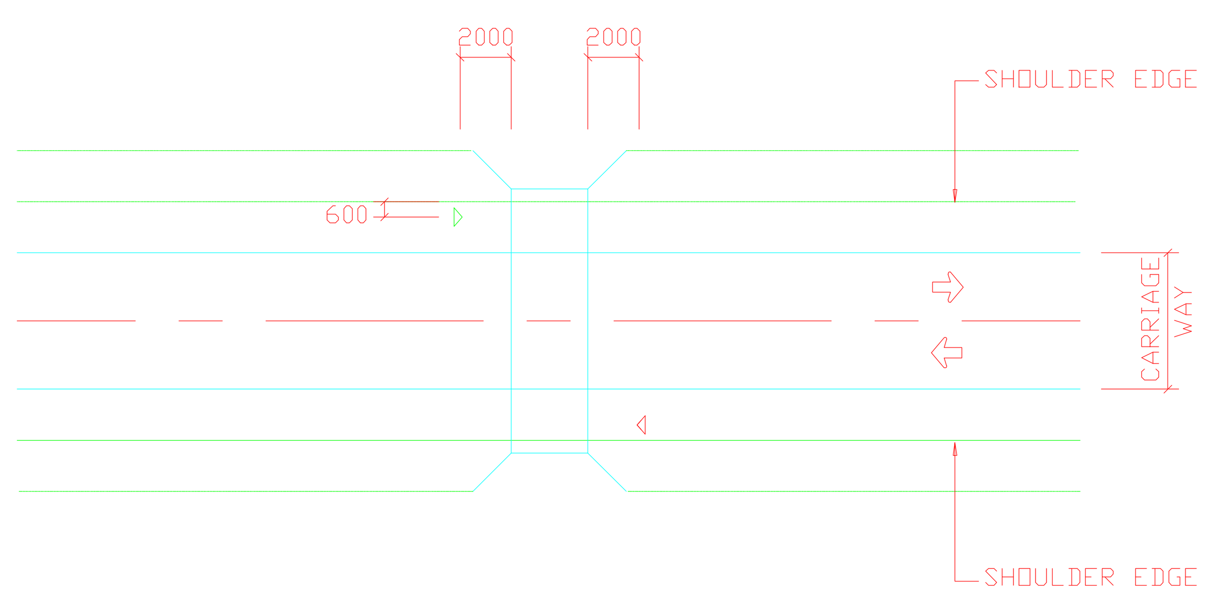


DETAIL OF STEEL LINKS
(INSIDE DIMENSIONS)



FRONT ELEVATION

DETAIL OF KM AND GUIDE POSTS



POSITIONING OF CULVERT MARKER POSTS

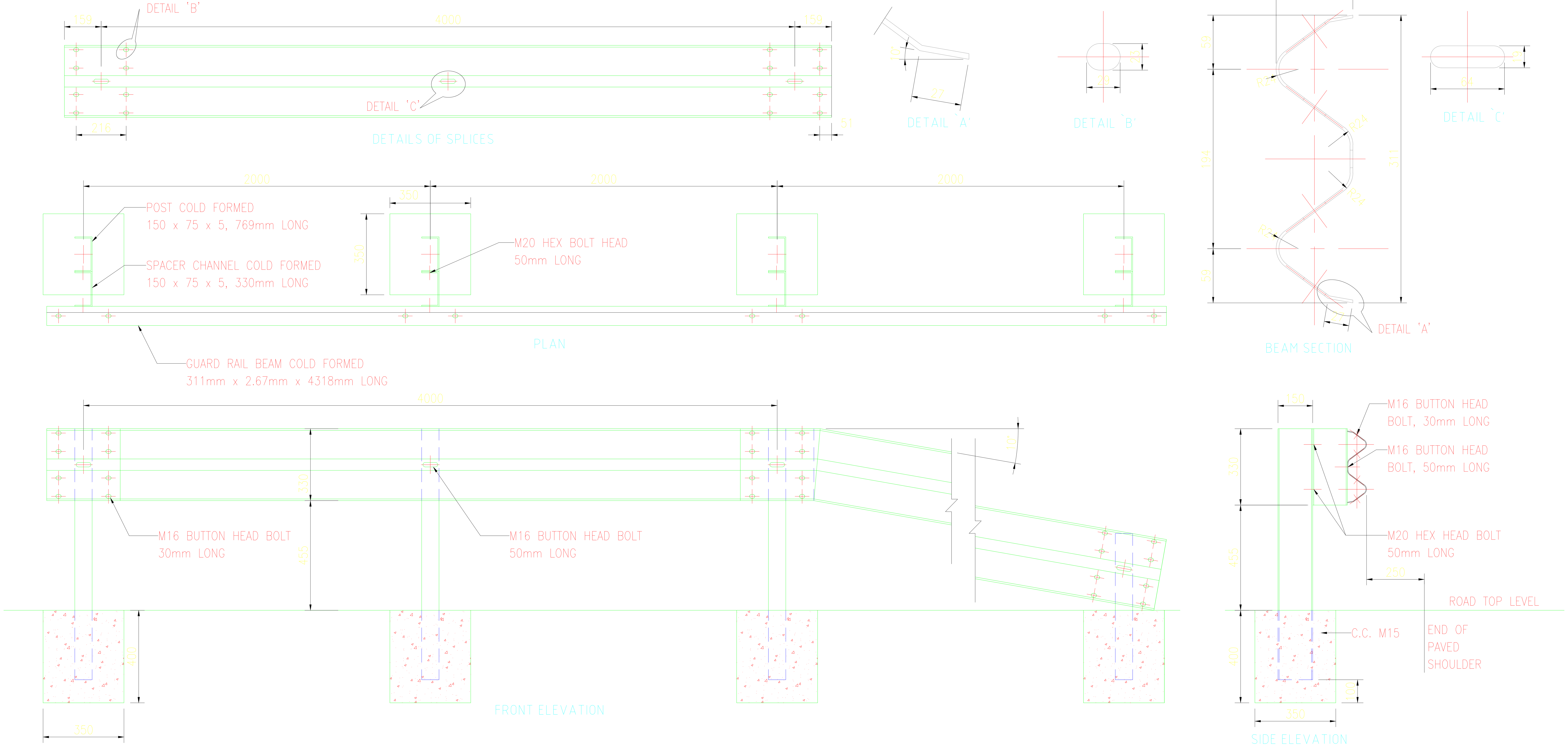
NOTES:

1. MARKERS ARE TO BE SITED ON THE LEFT HAND SIDE OF THE ROAD, MEASURED FROM THE DIRECTION OF THE DATUM AND FACING THE CARRIAGEWAY. SPACING TO BE 1km UNLESS OTHERWISE SPECIFIED.
2. THE DATUM TO BE CONFIRMED WITH THE RDA.
3. FRONT FACE PAINTED REFLECTIVE WHITE WITH LETTERS IN BLACK.
4. NOMINAL REINFORCEMENT TO BE PROVIDED.

NOTE:

1. CULVERT MARKER POSTS TO BE INSTALLED AT CULVERT LOCATIONS AS SHOWN ON THE DRAWING
2. Km POSTS TO BE INSTALLED EVERY km IN LHS AND RHS SHOULDER
3. AT EMBARKMENTS AND ON THE OUTSIDE OF CURVES GUIDE POSTS WILL BE INSTALLED AT 20M C/C OR AS DIRECTED BY THE ENGINEER.
4. THE POSTS MUST BE PAINTED WITH APPROVED WHITE COLOUR PAINT.
5. CONCRETE TO BE CLASS 20/20.
6. REINFORCING STEEL SHALL BE DEFORMED BARS CONFORMING TO SATCC M31-GRADE 400.

DETAILS OF W-BEAM CRASH BARRIERS



NOTE:

1. HEIGHT OF POSTS SHOULD BE 785mm ABOVE THE FINISHED ROAD LEVEL.
2. SPACING OF POSTS SHOULD BE 2.0m C/C.
3. 1 No. SPACER CHANNEL SHOULD BE PLACED AT EACH POST.
4. W-PROFILE FORMED CORRUGATED BEAMS (EFFECTIVE LENGTH OF 4318mm), 311mm x 83mm.
5. POST CONSISTS OF FORMED CHANNEL OF SIZE 150 x 75 x 5, 785mm LONG.
6. SPACER CONSISTS OF FORMED CHANNEL OF SIZE 150 x 75 x 5, 330mm LONG.
7. BUTTON HEAD BOLTS M16 x 30mm LONG, 8 Nos FOR THE SPLICING OF THE W PROFILE AT EACH LOCATION.
8. BUTTON HEAD BOLTS M16 x 50mm LONG, 1 Nos AT THE CONNECTION OF THE W BEAM TO SPACER.

NOTE:

9. HEX HEAD BOLTS M20 x 50mm LONG , 2 Nos AT THE CONNECTION OF THE SPACER TO POST.
10. THE BEAM ELEMENTS SHALL BE FORMED SHEETS HAVING NOMINAL WIDTH OF 483mm.
11. THE BASE MATERIAL OF THE CORRUGATED BEAM SHALL BE COMPLY TO FOLLOWING MECHANICAL PROPERTIES:-
    I. TENSILE STRENGTH, MIN=483 MPA. II. ELONGATION, in 2 inches, MIN = 12%
    III. YIELD, MIN=345 MPA.
12. ALL MEMBERS OF THE SYSTEM SHOULD BE HOT DIPPED GALVANIZED AND TO HAVE A MINIMUM COATING OF 550g/Sq m, EACH FACE IN CONFORMANCE TO RELEVANT M.O.S.T. SPECIFICATIONS (CLAUSE 810).
13. BEAMS TO BE ERECTED ON A RADIUS OF 46m (150') OR LESS SHALL BE SHOP CURVED TO APPROPRIATE CURVATURE.
14. CRASH BARRIERS ARE POSTED ON ALL SECTION OF EMBANKMENT WHOSE HEIGHT IS >= TO 3m, HORIZONTAL CURVES OF RADIUS < 170m AND ALSO AT MAJOR BRIDGE APPROACHES.

Appendix K: UCEM variables form

UCEM Variables Form

1. LABOUR

Information is revised annually by ABCEC & NUBEGW (Source: ABCEC)

1.1. Labour categories

S/No.	Description	Basic rate (K/hr)
L001	Foreman	
L002	Equipment operator	
L003	Labourer skilled (various classes)	
L004	Labourer	
L005	Watchman	

1.2. Variables for labour build up

S/No.	Description	Unit	Rate / Price
1	Working hours per day	hrs	
2	Working hours per week	hrs	
3	Working hours per month	hrs	
4	Working days per week	days	
5	Public holidays per year	day	
6	Annual leave	day	
7	Sick leave	day	
8	Compassionate leave	day	
9	Inclement weather	hrs	
10	Service benefit	hrs/ mth	
11	NAPSA	%/	
12	WCF	%/	
13	Medical	% of medical scheme	
14	HIV training/first aid	% of probation period	
15	Work suit (overalls)	K/no.	
16	Gumboots	K/pair	
17	Head gear	K/no.	
18	Raincoat	K/no.	
19	Uniform	K/no.	
20	Reflector vest	K/no.	
21	Safety shoes	K/pair	
22	Tool allowance (car / pl)	% of basic rate	
23	Housing allowance	% of basic rate	
24	Funeral benefit	K/event	
25	Max advance	K/event	
26	Incentive	K/day	
27	Overtime rate	% of basic rate	

S/No.	Description	Unit	Rate / Price
28	Lunch allowance	K/day	
29	transport	K/day	
30	UTH medical scheme	K/month	
31	Typing costs per page	K/ page	
32	Risk		

2. EQUIPMENT AND PLANT

2.1. General information

S/No	Description	Unit	Source
1	Insurance rate for equipment	%	Insurance companies
2	Road tax for Equipment	%	RTSA
3	Cost of diesel	L	Pump price
4	Cost of oil	L	Pump price

2.2. Information required for all equipment

S/No	Description	Unit	Source
1	Utilization Factor	%	Equipment Manufacturer / Supplier
2	Hours per annum	Hours	
3	Plant period	years	
4	*Purchase price	ZMK	
5	Percent for consumable replacement costs	%	

2.3. List of equipment

S/No	Description
PE-001	Air Compressor
PE-002	Batching and Mixing Plant (a) 30 m3 capacity
PE-003	Batching and Mixing Plant (b) 15 - 20 m3 capacity
PE-004	Batch type cold mixing plant 100-120 TPH capacity producing an average output of 75 tonne per hour
PE-005	Belt conveyor system
PE-007	Bitumen Pressure Distributor
PE-008	Bitumen Boiler oil fired
PE-009	Boat
PE-010	Cement concrete batch mix plant @ 175 cum per hour (effective output)
PE-011	Cement concrete batch mix plant @ 75 cum per hour
PE-012	Concrete Paver Finisher with 40 HP Motor
PE-013	Concrete Pump of 45 & 30 m3 capacity
PE-014	Concrete Bucket
PE-015	Concrete Mixer (a) 0.4/0.28 m3
PE-016	Concrete Mixer (b) 1 m3
PE-017	Crane (a) 80 tonnes

S/No	Description
PE-018	Cranes (b) 35 tonnes
PE-019	Cranes (c) 5tonnes
PE-020	Cranes (d) 3 tonnes
PE-021	Crane with grab 0.75 cum capacity
PE-022	Dozer D - 80 - A 12
PE-023	Dozer D - 50 - A 15
PE-024	Emulsion Pressure Distributor
PE-025	Front End loader 1 m3 bucket capacity
PE-026	Generator (a) 100/125 KVA
PE-027	Generator(b) 33/63 KVA
PE-028	GSB Plant 50 m3
PE-029	Hotmix Plant - 120 TPH capacity
PE-030	Hotmix Plant - 100 TPH capacity
PE-031	Hotmix Plant - 60 to 90 TPH capacity
PE-032	Hotmix Plant - 40 to 60 TPH capacity
PE-033	Hydraulic Chip Spreader
PE-034	Hydraulic Excavator of 1 m3 bucket
PE-035	Integrated Stone Crusher 100THP
PE-036	Integrated Stone Crusher 200 HP
PE-037	Kerb Casting Machine
PE-038	Mastic Cooker
PE-039	Mechanical Broom Hydraulic
PE-040	Motor Grader complete with scarifier, CAT 14 or equivalent
PE-041	Mobile slurry seal equipment
PE-042	Paver Finisher Hydrostatic with sensor control 100 TPH
PE-043	Paver Finisher Mechanical 100 TPH
PE-044	Piling Rig with Bantonite Pump
PE-045	Piling rig Including double acting pile driving hammer (Hydraulic rig)
PE-046	Pneumatic Road Roller
PE-047	Pneumatic Sinking Plant
PE-048	Pot Hole Repair Machine
PE-049	Prestressing Jack with Pump & access
PE-050	Ripper
PE-051	Rotavator
PE-052	Road marking machine
PE-053	Smooth Wheeled Roller 8 tonne
PE-054	Tandem Road Roller
PE-055	Tipper - 5 m3
PE-056	Tipper - 5 m3
PE-057	Tipper - 5 m3
PE-058	Tipper 5.5 m3 per 10tonnes 4 trips/hour
PE-059	Tipper - 10T
PE-060	Tipper - 20T
PE-061	Transit Mixer 4/4.5 m3
PE-062	Transit Mixer 4/4.5 m4
PE-063	Transit Mixer 3.0 m2

S/No	Description
PE-064	Transit Mixer 3.0 m3
PE-065	Tractor
PE-066	Tractor with Rotevator
PE-067	Tractor with Ripper
PE-068	Truck 5.5 m3 per 10 tonnes
PE-069	Vibratory Roller 8 tonne
PE-070	Water Tanker
PE-071	Wet Mix Plant 60 TPH
PE-072	Wet Mix Plant 75 TPH
PE-073	Epoxy Injection gun
PE-074	Plate compactor
PE-075	620HP RX-600e/ex Asphalt Milling Machine with a two-stage front loadout conveyor with 60° swing
PE-076	CAT RM 300 road reclaimer

3. MATERIAL

3.1. General information

Exchange rate **ZMK:US$** (source: BOZ)

3.2. List of material

S/No.	Description	Unit
M-001	Stone Boulder of size 150 mm and below at Crusher Plant	m3
M-002	Boulder with minimum size of 300 mm for Pitching at Site	m3
M-003	Coarse sand at Mixing Plant	m3
M-004	Coarse sand at Site	m3
M-005	Fine sand at Site	m3
M-007	Gravel/Quarry spall at Site	m3
M-008	Granular Material	m3
M-009	Filter media/Filter Material	m3
M-010	Close graded Granular sub-base Material 9.5 mm to 53 mm	m3
M-011	Close graded Granular sub-base Material 9.5 mm to 37.5 mm	m3
M-012	Close graded Granular sub-base Material 9.5 mm to 26.5 mm	m3
M-013	Close graded Granular sub-base Material 4.75 mm to 9.5mm	m3
M-014	Close graded Granular sub-base Material 2.36 mm to 9.5mm	m3
M-015	Close graded Granular sub-base Material 2.36 mm to 4.75mm	m3
M-016	Close graded Granular sub-base Material 75 micron mm to 4.75mm	m3
M-017	Close graded Granular sub-base Material 2.36 mm	m3
M-018	Stone crusher dust finer than 3mm with not more than 10% passing 0.075 sieve.	m3
M-019	Coarse graded Granular sub-base Material 2.36 mm & below	m3
M-020	Coarse graded Granular sub-base Material 75 micron mm to 4.75mm	m3

S/No.	Description	Unit
M-021	Coarse graded Granular sub-base Material 2.36 mm to 4.75 mm	m3
M-022	Coarse graded Granular sub-base Material 4.75 mm to 9.5 mm	m3
M-023	Coarse graded Granular sub-base Material 4.75 mm to 26.5 mm	m3
M-024	Coarse graded Granular sub-base Material 9.5 mm to 26.5 mm	m3
M-025	Coarse graded Granular sub-base Material 9.5 mm to 37.5 mm	m3
M-026	Coarse graded Granular sub-base Material 26.5 mm to 53mm	m3
M-027	Aggregates below 5.6 mm	m3
M-028	Aggregates 2.36 mm to 22.4 mm	m3
M-029	Aggregates 5.6 mm to 22.4 mm	m3
M-030	Aggregates 2.8 mm to 45 mm	m3
M-031	Aggregates 22.4 mm to 45 mm	m3
M-032	Aggregates 2.8 mm to 53 mm	m3
M-033	Aggregates 22.4 mm to 53 mm	m3
M-034	Aggregates 2.8 mm to 63 mm	m3
M-035	Aggregates 45 mm to 63 mm	m3
M-036	Aggregates 45 mm to 90 mm	m3
M-037	Aggregates 5 mm to 10 mm	m3
M-038	Aggregates 0.09 mm to 11.2 mm	m3
M-039	Aggregates 0.09 mm to 13.2 mm	m3
M-040	Aggregates 5.6 mm to 13.2 mm	m3
M-041	Aggregates 10 mm to 13.2 mm	m3
M-042	Aggregates 10 mm to 25 mm	m3
M-043	Aggregates 10 mm to 20 mm	m3
M-044	Aggregates 6 mm to 19 mm	m3
M-045	Aggregates 19 mm to 37.5mm	m3
M-046	Aggregates 25 mm to 37.5mm	m3
M-047	Aggregates 6 mm nominal size	m3
M-048	Aggregates 10 mm nominal size	m3
M-049	Aggregates 13.2/12.5 mm nominal size	m3
M-050	Aggregates 20 mm nominal size	m3
M-051	Aggregates 25 mm nominal size	m3
M-052	Aggregates 40 mm nominal size	m3
M-053	AC pipe 100 mm dia	m
M-054	Aluminium Paint	litre
M-055	Aluminium alloy plate 2mm Thick	m2
M-056	Aluminium alloy/galvanised steel	tonne
M-057	Aluminium sheeting fixed with encapsulated lens type reflective	m2
M-058	Bearing (Elastomeric bearing assembly consisting of 7 internal layers of elastomer bonded to 6 nos. internal reinforcing steel laminates by the process of vulcanisation,)	No.
M-059	Bearing (Pot type bearing assembly consisting of a metal piston supported by a disc, PTFE pads providing sliding surfaces against stainless steel mating together with cast steel assemblies/fabricated structural steel assemblies duly painted with all components	No.
M-060	Bearing (PTFE sliding plate bearing assembly of 80 tonnes)	No.
M-061	Bentonite	kg
M-062	Binding wire	kg

S/No.	Description	Unit
M-063	Bitumen (60-70 grade)	tonne
M-054	CRMB-55	tonne
M-065	Bitumen (emulsion - SS1)	tonne
M-066	Bitumen (emulsion-RS1)	tonne
M-067	Bitumen (modified graded)	tonne
M-068	Concrete brick	each
M-069	Hollow concrete blocks 200mm	each
M-070	Hollow concrete blocks 150mm	each
M-071	Hollow concrete blocks 100mm	each
M-072	C.I. shoes for the pile	kg
M-073	Cement	tonne
M-074	Cold twisted bars (HYSD Bars)	tonne
M-075	Collar for joints 300 mm dia	No.
M-076	Compressible Fibre Board(20mm thick)	m2
M-077	Corrosion resistant Structural steel	tonne
M-078	Credit for excavated rock found suitable for use	m3
M-079	Curing compound	litre
M-080	Delineators per the standard drawing	each
M-081	Earth Cost or compensation for earth taken from private land	m3
M-082	Electric Detonators @ 1 detonator for 1/2 gelatin stick of 125g each	100 no.
M-083	Epoxy compound with accessories for preparing epoxy mortar	kg
M-084	Epoxy primer (Sealant Primer)	kg
M-085	Galvanised MS flat clamp	No.
M-086	Galvanised structural steel plate 200 mm wide, 6 mm thick, 24 m long	kg
M-087	Gelatin 80%	kg
M-088	GI bolt 10 mm Dia	No.
M-089	Grouting pump with agitator	hour
M-090	Hot applied thermoplastic compound	litre
M-091	HTS strand	tonne
M-092	Joint Sealant Compound	kg
M-093	M.S. Clamps	No.
M-094	M.S. Clamps	kg
M-095	Mild Steel bars	tonne
M-096	Nuts and bolts	kg
M-097	Paint	litre
M-098	Pavement Marking Paint	litre
M-099	Pipes 200 mm dia, 2.5 m long for drainage	metre
M-100	Plastic sheath, 1.25 mm thick for dowel bars	m2
M-101	Pre moulded Joint filler 25 mm thick for expansion joint.	m2
M-102	Pre-coated stone chips of 13.2 mm nominal size	m3
M-103	Pre-moulded asphalt filler board	m2
M-104	Pre-packed cement based polymer concrete of strength 45 MPA at 28 days	kg
M-105	Quick setting compound	kg
M-106	Random Rubble Stone	m3
M-107	Culvert pipe 1200 mm dia (2.4m long)	m
M-108	Culvert pipe 1000 mm dia	m

S/No.	Description	Unit
M-109	Culvert pipe 900 mm dia	m
M-110	Culvert pipe 600 mm dia	m
M-111	Culvert pipe 300 mm dia	m
M-112	Reflectorizing glass beads	kg
M-113	Sand bags (Cost of sand and Empty cement bag)	No.
M-114	Selected earth	m3
M-115	Separation Membrane of impermeable plastic sheeting 125 micron thick	m2
M-116	Sheathing duct	m
M-117	Sludge / Farm yard manure @ 0.18 m3 per 100 m2 at site of work for turfing	m3
M-118	Square Rubble Coarse Stone	m3
M-119	Steel helmet and cushion block on top of pile head during driving.	kg
M-120	Steel pipe 25 mm dia	m
M-121	Steel pipe 50 mm dia	m
M-122	Steel wire rope 20 mm	kg
M-123	Steel wire rope 40 mm	kg
M-124	Strip seal expansion join	m
M-125	Structural Steel	tonne
M-127	Super plastisizer admixture IS marked as per 9103-1999	kg
M-128	Synthetic Geogrids as per clause 3102.8 and approved design and specifications.	m2
M-129	Through and bond stone	each
M-130	Tube anchorage set complete with bearing plate, permanent wedges etc	No.
M-131	Unstacked lime	tonne
M-132	Water	Litre
M-133	Water based cement paint	litre
M-134	Wire mesh 50mm x 50mm size of 3mm wire	kg
M-135	Precast box culvert 1200mm	m
M-136	Guard rails	m
M-137	Kerbs	m

Appendix L: Peer reviewed journal articles and conference proceedings

Peer reviewed journals

i. **Mwiya B.**, Muya, M., Kaliba, C. and Mukalula, P. (2015), *Construction Unit Rate Factor Modelling Using Neural Networks,* World Academy of Science, Engineering and Technology, International Science Index 97, ISSN: 1307-6892 International Journal of Civil, Architectural, Structural and Construction Engineering, 9(1), 29 - 34.

Peer reviewed conference proceedings

i. **Mwiya B.**, Muya M., Kaliba C., (2016) *Adoption of Best Value Selection Method in the Zambian Road Sector.* DII-2016 Conference on Infrastructure Development and Investment Strategies for Africa, ISBN: 978-0-620-70336-9 on 31 August -3 September 2016 at Chrismar Hotel, Livingstone, Zambia.

ii. **Mwiya B.,** Muya M. and Kaliba C. (2016) *Opportunities for Harmonisation of Ancillary Roadworks under Series 5000 of the SATCC Standards and Specifications*, The Engineering Institution of Zambia (EIZ) Symposium on April, 22 at Avani Victoria Falls Resort, Livingstone, Zambia

iii. **Mwiya B.**, Muya M., Kaliba C., Mukalula, P. (2015), *Construction Unit Rate Factor Modelling Using Neural Networks,*ICCSEE 2015: International Conference on Civil, Structural and Environmental Engineering on January, 13-14, 2015 at Zurich, Switzerland

iv. **Mwiya B.,** Muya M., Kaliba C., and Mukalula P. (2014) *Factors affecting construction unit rates in the Zambian road sector*. DII-2014 Conference on Infrastructure Investments in Africa,ISBN: 978-0-86970-782-1 on 25-26 September 2014 at Livingstone, Zambia.

Construction Unit Rate Factor Modelling Using Neural Networks

Balimu Mwiya, Mundia Muya, Chabota Kaliba, Peter Mukalula

***Abstract*—**Factors affecting construction unit cost vary depending on a country's political, economic, social and technological inclinations. Factors affecting construction costs have been studied from various perspectives. Analysis of cost factors requires an appreciation of a country's practices. Identified cost factors provide an indication of a country's construction economic strata. The purpose of this paper is to identify the essential factors that affect unit cost estimation and their breakdown using artificial neural networks. Twenty five (25) identified cost factors in road construction were subjected to a questionnaire survey and employing SPSS factor analysis the factors were reduced to eight. The 8 factors were analysed using neural network (NN) to determine the proportionate breakdown of the cost factors in a given construction unit rate. NN predicted that political environment accounted 44% of the unit rate followed by contractor capacity at 22% and financial delays, project feasibility and overhead & profit each at 11%. Project location, material availability and corruption perception index had minimal impact on the unit cost from the training data provided. Quantified cost factors can be incorporated in unit cost estimation models (UCEM) to produce more accurate estimates. This can create improvements in the cost estimation of infrastructure projects and establish a benchmark standard to assist the process of alignment of work practises and training of new staff, permitting the on-going development of best practises in cost estimation to become more effective.

***Keywords*—**Construction cost factors, neural networks, roadworks, Zambian Construction Industry.

I. Introduction

CONSTRUCTION is a vital activity in the Zambian economy. The national roads system in Zambia is experiencing a period of exceptional activity. The roads' share of GDP increased from 1.5% to 4.1% in just two years [1]. There is concern as to whether the existing road sector in Zambia is operating efficiently and whether it can handle the rising changes effectively. In Zambia, the construction industry is perceived to exhibit high margins of profit. Consequently, key stakeholders have in the recent past called for an informed position on prevailing market rates in the Zambian construction industry. As a result attention has been focused on pricing of construction unit rates.

Unit cost estimating, aided by sound engineering judgement, is the most definitive estimate technique and uses information down to the lowest level of detail available. This is the most common approach to cost estimation used in Zambia. Reference [2] describes the unit cost estimation approach as, where a unit cost is assigned to each task as represented by the bill of quantities and the total cost is the summation of the products of the quantities multiplied by the corresponding unit costs. Estimating in Zambia is carried out by a wide range of personnel who subscribe to protocols that are broadly understood, but are not consistently well documented. Approaches to estimating usually vary between the contractor's, service providers and Client's organisation and is not reflected in a documented or accepted industry standard resulting in continued inconsistencies. Industry regulators and public institutions have indicated that there was a notable trend in varying costs of construction from project to project and from one public institution to another, that it had become increasingly difficult to ascertain the true cost of projects and thereby unable to guarantee value for [3]. Construction regulatory bodies require reliability in estimation of project costs to understand prevailing market rates in the Zambian construction industry.

A review of literature showed that there was no single approach to developing construction unit rates (CUR). Generally, road construction works can be considered as a combination of two types of items. Firstly, those that can be estimated through some form of calculation, for example, the direct labour, material and equipment inputs. In this category the cost relationships between labour, material and plant are known. And secondly, indirect items such as those that cannot be calculated directly from labour, material and equipment costs. The difference between actual direct costs and prevailing market rates is referred to as the 'economic strata' or 'cost structure' which reflects the peculiarities of the local setting usually qualitative in nature such as prevailing project conditions, contractor capacity and other risk factors. Though construction cost factors may be identical internationally, it is the impact on the unit cost that varies according to a country's political, economic, social and technological inclinations.

The study focuses on deriving an objective scientific prediction of the economic strata using neural networks. Neural networks (NN) are a form of artificial intelligence capable of capturing the relations between independent and dependent variables. One of the most important and exciting characteristics of NN is their ability to learn and self-organize [4]. Reference [5] indicated that neural networks have advantages when dealing with data that does not adhere to the generally chosen low order polynomial forms, or data for

B. Mwiya is with the Department of Civil and Environmental Engineering, University of Zambia, Lusaka, Zambia (phone: +260 965 837400; e-mail: balimu.mwiya@ unza.zm).

M. Muya is Dean with the School of Engineering, University of Zambia, Lusaka, Zambia (e-mail: mmuya@ unza.zm).

C. Kaliba is with the Department of Civil and Environmental Engineering University of Zambia, Lusaka, Zambia (e-mail: chabota.kaliba@gmail.com).

P. Mukalula is with the Copperbelt University, Kitwe, Zambia (e-mail: musomuko@yahoo.com).

which there is little a priori knowledge of the appropriate cost estimating relationship (CER). A CER is functional relationship between changes in cost and the factor or factors upon which the cost depends resulting in a mathematically-fitted function [6].

To achieve the aim of the research, 25 identified construction cost factors were subjected to a questionnaire survey. The factors were reduced to eight (8) using SPSS factor analysis. The 8 factors were then analysed using NN to calculate the influence on unit costs. The resulting ratio of the factors namely political environment, contractor capacity, financial delays, project feasibility and overhead & profit was 4:2:1:1:1. Project location, material availability and corruption perception index had minimal impact on the unit cost. Quantified cost factors can be incorporated in unit cost estimation models to produce more accurate estimates. This can create improvements in the cost estimation of infrastructure projects and establish a benchmark standard. This standard will assist the process of alignment of work practises and training of new staff, allowing the on-going development of best practises in cost estimation to become more effective.

II. Literature Review

Accuracy of the estimate depends on the accuracy of available information. Foundation of unit cost-based estimating, sometimes referred to as first principle estimating, is the calculation of project-specific costs based on a detailed study of the resources, such as labour hours, material costs, equipment costs, subcontractor costs, or other unit-cost-type items required to accomplish each activity of work contained in the project work breakdown structure (WBS) or bill of quantities (BOQ). Indirect costs, overhead costs, contingency, and escalation are then added as necessary. Drawings, specifications, and project scope are used to identify activities that make up the BOQ. A BOQ serves three purposes: first and foremost it must be prepared with the objective of providing the estimator with as accurate a picture of the project as possible so as to provide a proper basis for pricing; second, it should enable the employer to compare tenders on an equal basis; and third it will be used to evaluate the work executed for payment purposes [7].

A study carried out by [8] investigated various cost estimation methods used in the Zambia construction industry. It revealed that the most common method was the use of rates based on past contracts with an allowance for inflation followed by building up of unit rates from first principles and finally use of computer software. Reference [9] observed that use of previous tender rates was common because of lack of experienced cost estimators in the bidding firm and the reduced duration of coming up with an estimate. This trend in Zambia indicated that estimate accuracy was the least requirement by the bidders perhaps due to the lack of cost estimate accuracy classification as established by professional quantity surveying bodies in other countries.

The construction economic strata consist of various factors that influence prevailing market rates used. Reference [10] stated that in cost estimation choosing cost drivers was the most important step since the model's accuracy was based upon selecting the relevant and appropriate cost drivers. Literature identifies various factors that affect construction cost with varying impacts in different parts of the world.

In Palestine, the top three factors were location of project (hot areas), segmentation of Gaza strip and closure of Gaza strip [11]. Closure and blockade of borders indicate security concerns from contractors' perspective. In the United States of America, the top three factors were project scope, land acquisition and utility relocation [12]. These factors reflect the developed nature of the country. Reference [13] revealed that fluctuation in prices of materials, cash flow & financial difficulties faced by contractors and shortage of site workers were the top three factors in Malaysia. But it was shortage of materials that Nigerians had to contend with followed by financing methods and payments for completed works and poor contract management [14]. These factors reveal an insight into the construction economic strata of the various countries. It can be deduced from literature that periodic review of cost factors was essential because of country's constant political, economic social and technological transformation.

Though there is no limit on the number of factors or variables to be used in NN. Reference [15] stated that the number of attributes assumed to have an effect on cost should be small because the architectural complexity increases with the number of attributes, requiring more training samples to reach a given accuracy, yet training samples were usually scarce in cost estimation. Literature on similar studies indicated factors of ten (10) or less. Reference [16] used 9 factors to determine preliminary estimate of time and cost in urban road construction using neural networks. Reference [17] also used 9 factors when investigating parametric cost estimation of road projects using artificial neural networks. 5 factors were employed in modelling construction labour production rates using artificial neural network [18].Reference [19] used 9 factors in developing a preliminary cost estimate of highway construction using neural networks.

TABLE I
LIST OF COST FACTORS AFTER PARETO ANALYSIS

1.	Location	8.	Exchange Rate	17.	Topography
2.	Hauling distance	9.	Contractor type	18.	Contractor selection method
		10.	Duration		
3.	Delayed payment	11.	Project scope	19.	Material Shortages
		12.	Detour construction	20.	Contractor size
4.	Project planning			21.	Overhead & Profit
		13.	Contract financing	22.	Corruption Perception Index
5.	Material Source	14.	Labour	23.	Fuel
6.	Equipment availability	15.	Contractor cash-flow	24.	Project supervision & management
7.	Project need	16.	Political risk	25.	Client type

Determination of the cost factors for the study used a two-step process. Firstly 45 cost factors were identified from literature. These were subjected to expert opinion through structured interviews by 10 industry experts. From the interviews, factors were ranked using frequency statistics. The

Pareto Analysis was then used to determine the vital few. Pareto Analysis is a statistical technique in decision making used for the selection of a limited number of tasks that produce significant overall effect. From the Pareto Principle (also known as the 80/20 rule) the influencing factors were reduced to 22. Three (3) factors were added to the list following expert opinion recommendation. The 25 factors subjected to a questionnaire survey are shown in Table I.

From Table I, factor 1 was the most influential and factor 22 the least influential with 23-25 as the added factors.

III. Research Methodology

To obtain a conclusive result on factors influencing road construction unit rates, the 25 factors were subjected to a questionnaire survey. Respondents were asked questions regarding the impact of cost factors on unit rates based on the Likert scale of 1 to 5 where 1 meant no impact and 5 meant extremely high impact.

A. Population and Sample Size

The targeted research population consisted of civil engineers with experience in cost estimation of roadworks. Equation (1) was used to determine the sample size of unlimited population [20], [21].

$$ss = \frac{z^2 \times p \times (1-p)}{c^2} \quad (1)$$

where: z = Z value (e.g. 1.96 for 95% confidence level); p = percentage picking a choice, expressed as decimal (0.5 used for sample size needed); c = confidence interval, expressed as decimal (0.5 = ±5); ss = sample size

$$ss = \frac{1.96^2 \times 0.5 \times (1-0.5)}{0.5^2} = 384 \quad (2)$$

The correction for finite population is:

$$NewSS = \frac{ss}{1+\frac{ss-1}{pop}} \quad (3)$$

where: pop = population

$$NewSS = \frac{384}{1+\frac{384-1}{108}} = 84 \quad (4)$$

TABLE II
Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	6.518	26.073	26.073	6.518	26.073	26.073	3.738	14.953	14.953
2	3.652	14.608	40.681	3.652	14.608	40.681	3.328	13.311	28.265
3	2.665	10.659	51.340	2.665	10.659	51.340	3.105	12.418	40.683
4	2.139	8.556	59.896	2.139	8.556	59.896	2.711	10.846	51.529
5	1.876	7.506	67.402	1.876	7.506	67.402	2.168	8.674	60.203
6	1.574	6.295	73.697	1.574	6.295	73.697	2.158	8.631	68.833
7	1.239	4.957	78.654	1.239	4.957	78.654	1.928	7.711	76.544
8	1.171	4.684	83.338	1.171	4.684	83.338	1.698	6.794	83.338
9	.976	3.905	87.242						
10	.866	3.463	90.706						
11	.568	2.271	92.977						
12	.485	1.939	94.916						
13	.345	1.380	96.296						
14	.293	1.172	97.468						
15	.276	1.103	98.571						
16	.180	.720	99.291						
17	.130	.519	99.810						
18	.047	.190	100.000						
19	3.664E-16	1.466E-15	100.000						
20	1.570E-16	6.279E-16	100.000						
21	1.010E-16	4.041E-16	100.000						
22	5.574E-17	2.230E-16	100.000						
23	-7.602E-17	-3.041E-16	100.000						
24	-2.913E-16	-1.165E-15	100.000						
25	-4.500E-16	-1.800E-15	100.000						

The research population targeted all the 72 large scale contractors in National Council for Construction (NCC) grades 1 – 3 in the R (road) category. At the time of the survey there were 26 registered civil engineering consulting firms with the Association of Consulting Engineers of Zambia (ACEZ) and 10 clientele organisations that dealt with estimation of roadworks. The total population size was 108 and the calculated sample size using (4) was 84. The questionnaires were distributed proportionately to the three groups as follows:

- Contractors – 84 x 72/108 = 56 (actual distribution = 30);
- Consultants – 84 x 26/108 = 20 (actual distribution = 20); and
- Clients – 84 x 10/108 = 8 (actual distribution = 8).

A total of 58 questionnaires were distributed because some contractors could not be located and the contact details with the registration body did not work. The response rate was 69%. Statistical analysis was conducted using Statistical Package for Social Sciences (SPSS). Reference [22] shows that factor analysis can yield good quality results for sample sizes less than 50. After establishing the influencing factors, prediction of the breakdown of the factors was done using NeuroShell2, an artificial neural network software.

IV. Findings And Discussion

A. Factor Analysis

In this study, SPSS factor analysis was performed to reduce the factors further by analysing the correlation between the variables and that the grouped the factors were statistically significant. The principal components extraction was used. Each eigenvalue represents the amount of variance that has been captured by one component. Table II shows the eigenvalues and proportions of variance for the components. From Table II, the total of the rotation sums of squared loadings was 1 or more in eight components.

To classify the components, an orthogonal factor rotation analysis was conducted, and the rotated component matrix was analysed, as given in Table III. The rotation method used was Varimax with Kaiser Normalization supressing variable values less than 0.400.

TABLE III
ROTATED COMPONENT MATRIX

	Component							
Variable	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Contractor_Size	.837							
Contractor_Type	.819							
Financial_Status_or_Cashflow_of_Contractor	.815							
Client_Type	.755							
Hauling_Distance		.815						
Location_of_the_Project		.814						
Fuel		.756						
Exchange_Rate		.634	.503					
Procurement	.536	.631						
Payments			.804					
Construction_Workers			.768					
Topography			.766					
Detour_Construction			.662					
Project_Scope				.817				
Contract_Financing				.751				
Project_Planning				.701				
Project_Need	.499			.527				
Project_Management	.445				.722			
Overhead_and_Profit					-.710			
Plant_and_Equipment					.680			
Material_Sources						.881		
Material_Shortages						.836		
Corruption_Perception_Index							.846	
Project_Duration							-.709	
Political_Interference								.844

The eight components were reclassified and named according to the loading of the variables in the rotated solution ensuring that the factor name is brief and communicates the nature of the underlying factors. The contractor variables loaded well on the first component reflecting how client perceives the contractor. The principal first factor thus labelled 'contractor capacity' accounts for 26.073% of the total variance and contains seven variables. The second component appears to be reflecting location of the project versus economy. It is labelled 'project location' and has five variables representing 14.608% of the total variance. The third component labelled 'financial delays' accounts for 10.659% of the total variance, with five variables and shows the effect of delayed payments on the exchange rate, construction workers and the type of work to be carried out. The fourth component is focused on the projects pre-planning activities. It is labelled 'project feasibility' with four variables and represents 8.556% of the total variance. The fifth component is more interesting, with a negative loading on overheads and profit. It has three variables reflecting overheads and profit with regards to plant, equipment and the projects management's capacity. It is labelled 'overhead and profit' and represents 7.506% of the total variance. Component six labelled 'material availability' is straight forward and reflects material factors with two variables representing 6.295% of the total variance. The seventh component is also interesting, with a negative loading reflecting concern for corruption versus duration of the project. It has been labelled 'corruption profile' with two variables and accounts for 4.957% of the total variance. The last component eight labelled 'political risk' reflects concern for political intrusion. It has one variable and accounts for 4.684% of the total variance. The renamed eight factors are shown in Table IV.

TABLE IV
NAMING OF COMPONENTS AND ASSOCIATED INPUT NODES

Component	Cost factor	Factor Input for NN
1	Contractor capacity	Capacity of contractor 1 = Grade 1, 2 = Grade 2, 3 = Grade 3, 4 = Grade 4, 5 = Grade 5, 6 = Grade 6, 7 = ungraded
2	Project Location	Distance in km from Lusaka or urban location 1 = very near (<100km), 2 = near (101-300km), 3 = average (301-500km), 4 = far (501-700km), 5 = very far (701-900km), 6 = extremely far >901km
3	Financial delays	Number of days payment is delayed 1= 0 days 2= up to 30 days, 3= 31-60 days, 4= 61-90 days, 5= 91-180days, 6= above 180 days
4	Project feasibility (pre-construction)	1= very good, 2= good, 3= satisfactory, 4= poor, 5= unacceptable
5	Overheads and profit	1 = 0%, 2 = 5%, 3 = 10%, 4 = 15%, 5 = 20%, 6 = 25%, 7 = 30%, 8 = above 35%
6	Materials availability	1 = available locally, 2 = available imported, 3 = shortages, 4= severe shortages
7	Corruption profile	CPI compiled by Transparency International 1=very clean (100-80), 2= clean (79-60), 3= moderate (59-40), 4= corrupt (39-20), 5= highly corrupt (19-0)
8	Political risk	Political interference 1=none, 2= low, 3= moderate, 4= high, 5= very high

B. Neural Network Analysis

NeuroShell2 was selected because of its classic neural network paradigms, its popularity amongst researcher and its user friendly graphical user interface (GUI) as shown in Fig. 1. NeuroShell2 has five network architectures that include different learning paradigms namely: Backpropagation (BP); Kohonen; Probabilistic Neural Network (PNN); General Regression Neural Network (GRNN); and Group Method of Data Handling or Polynomial Nets (GMDH Network). All the networks are supervised type of network, trained with both inputs and outputs except the Kohonen network.

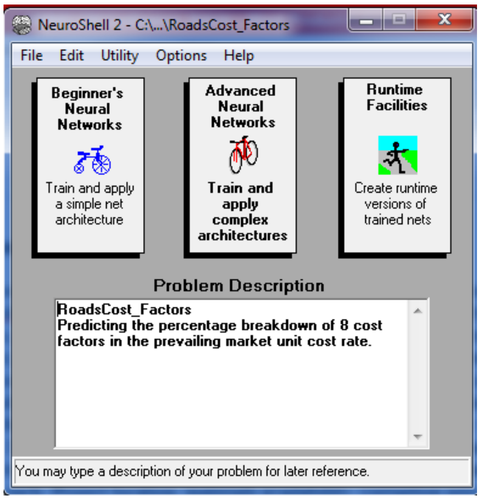


Fig. 1 Screen shot of NeuroShell 2 GUI

The Kohonen architecture was selected because it is unsupervised and has the ability to learn without being shown correct outputs in sample patterns. The 8 factors were analysed. The training epochs were increased steadily from 1000, 5000, 10,000 and 50,000. The results after 10,000 epochs remained the same. The Kohonen Self Organizing Map network was able to separate data patterns as shown in

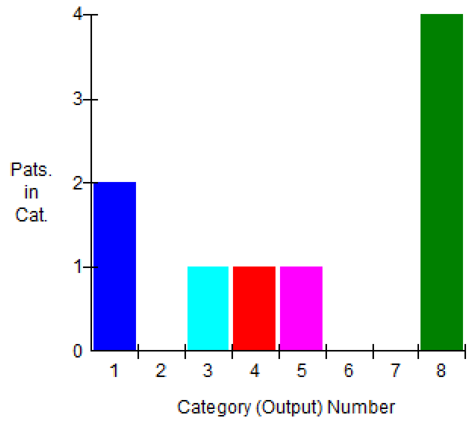


Fig. 2 Graphical representation of NN output
1 = Contractor capacity, 2 = Project Location, 3 = Financial delays, 4 = Project feasibility, 5 = Overheads and profit, 6= Materials availability, 7 = Corruption profile, 8 = Political risk

REFERENCES

[1] G. Raballand and A. Whitworth "The Crisis in the Zambian Road Sector", Working Paper No. 5, Zambia Institute for Policy Analysis and Research (ZIPAR), 2012, Lusaka.
[2] C. Hendrickson, Project Management for Construction, Fundamental Concepts for Owners, Engineers, Architects and Builders, 2008, (available online: http://pmbook.ce.cmu.edu/ (accessed 05/11/20139))
[3] Zambia Public Procurement Authority, Consulting services to undertake an assessment of the prevailing market rates in the construction industry, Request for proposals, ZPPA, Zambia, 2014.
[4] J. De la Garza and K. Rouhana, Neural Network versus parameter-based application. Cost Engineering, 37(2) 1995, pp.14-18.
[5] A. K. Mason and A. E. Smith, Cost Estimation Predictive Modeling: Regression versus Neural Network. Engineering Economist 42, (2) 1997, pp. 137-161.

[6] AACE International, Cost Engineering Terminology, Recommended Practice No. 10S-90, TCM Framework: General Reference, Association for the Advancement of Cost Engineering (AACE),2013
[7] Langdon, D., Spon's Civil Engineering and Highway Works Price Book 2009, Spon Press, 2009
[8] J. Mashilipa, An investigation on the effects and their implications of using British outputs in Estimating in the Zambian Construction Industry, BSc (Building) Unpublished thesis, Copperbelt University, Zambia, 2004.
[9] *Ibid*
[10] E. J Blocher, E. David, G. C. Stout and K. H. Chen, Cost management; A strategic emphasis 4th ed., McGraw Hill, 2008.
[11] A. Enshassi, S. Mohamed, and I. Madi, Contractors' Perspectives towards Factors Affecting Cost Estimation in Palestine. Jordan Journal of Civil Engineering, 1 (2) 2007, pp. 186-193.
[12] A. Trombka and S. Downey, A Study of County Road Project Cost and Schedule Estimates, Office of Legislative Oversight, Montgomery County, Maryland Report Number 2008-04, 2008, (available online https://www.montgomerycountymd.gov/olo/resources/files/2008-4.pdf (accessed 05/07/2014))
[13] A.H. Memon, I.A. Rahman, M.R. Abdullah, and A.A.A. Azis, Factors Affecting Construction Cost Performance in Project Management Projects: Case of Mara Large Projects. Proceedings of Post Graduate seminar on Engineering, Technology and Social Science. 29-30 November 2010, Universiti Tun Hussein Onn Malaysia, 2010
[14] A.U. Elinwa and S.A. Buba, Construction cost factors in Nigeria, Journal of Construction Engineering and Management. 119 (4), 1993, pp. 698-713.
[15] J. Bode, Neural Networks for Cost Estimation, Cost Engineering Journal 40 (1) 1998, pp.25-30
[16] I. Peško, M. Trivunić, G. Cirović and V. Mučenski, A preliminary estimate of time and cost in urban road construction using neural networks Technical Gazette 20 (3), 2013, pp. 563-570 (accessed 16/01/2014)
[17] A. J. Hasan, Parametric Cost Estimation of Road Projects Using Artificial Neural Networks, M.Sc. Unpublished thesis, The Islamic University, Gaza, 2013
[18] S. Muqeem, A. Idrus, F. M. Khamidi, J.B. Ahmad, and S.B. Zakaria, Construction labor production rates modeling using artificial neural network, Journal of Information Technology in Construction (ITcon), Vol. 16, 2011, pp. 713-726, (available online http://www.itcon.org/2011/42 (accessed on 09/04/2014))
[19] A. Hashem, P.A. Alex, and M. Tantash, Preliminary Cost Estimation of Highway Construction Using Neural Networks, Cost Engineering 41, (3) 1999, pp. 19-24
[20] D. R. Cooper and P.S. Schindler, Business research methods 11th ed., McGraw Hill, 2011, pp.390-397
[21] Creative Research Systems, Sample Size Formula, (available online: http://www.surveysystem.com/sample-size-formula.htm (accessed on 09/04/2014))
[22] J. C. F. de Winter, D. Dodou, and P. A. Wieringa, Exploratory Factor Analysis with Small Sample Sizes, Multivariate Behavioral Research, 44, 2009, pp147–181

DII-2016-009

Adoption of Best Value Selection Method in the Zambian Road Sector

Balimu Mwiya[1], Mundia Muya[2], Chabota Kaliba[3]

Abstract

The intricacies of bidding and procurement in public infrastructure investment, if well managed, dictate the success of a project. They provide value for money (VfM) in the use of public funds. The prominence of VfM in the development agenda is that there is no fixed price of public infrastructure delivery. Two roads with the same parameters built in the same geographical location will never have the same price. However, assessing VfM is not a simple task in a developing country like Zambia because of limited standards, non-adherence to regulations and non-availability of reliable statistics. This is compounded by multiple stakeholders and their perspective of value for money. The traditional method of procurement is the most common in the Zambian road sector. Contractor selection is based on least cost. However, evidence suggests that this approach accounts for poor performance, delays and cost overruns. The aim of the paper is to propose the adoption of the Best Value Selection (BVS) method which utilises the concept of VfM for the Zambian road sector. The results presented are from a broader study carried out on the analysis of unit rates for road works in Zambia. The research method involved a desk review of 254 project executed during a ten year period from 2005 to 2014. Using findings from desk study and questionnaire survey a comparative analysis was made between least cost selection (LCS) and BVS. With the provision of accurate Engineer's estimates, the Zambian road sector can migrate from LCS to BVS in procurement of works. BVS involves consideration of cost, preliminary and project specific indicators. Findings show that for BVS adoption, open and transparent accurate Engineer's estimates are a requirement and bidders would decide at the onset whether to bid for the work or not. The Engineer's estimate is viewed as a baseline in terms of cost efficiency, effectiveness and economic variables.

Keywords: best value selection, procurement of works, value for money, Zambian road sector

1. Introduction

Road infrastructure provides a fundamental foundation to the performance of national economies, delivering a wide range of economic and social benefits. For a landlocked country, the Zambian road network is one of the country's largest public sector assets. The Government of the Republic of Zambia (GRZ), through the Road Development Agency (RDA) embarked on a ten year Road Sector Investment Programme (RoadSIP II) from 2003 to 2013. The focus of RoadSIP II was to bring the Core Road Network (CRN) into serviceable

[1]Lecturer; Department of Civil and Environmental Engineering; University of Zambia; P.O. Box 32379, Lusaka, Zambia; Email: balimu.mwiya@unza.zm or mwiyab49@gmail.com
[2]Dean; School of Engineering; University of Zambia; P.O. Box 32379, Lusaka, Zambia; E-mail: mmuya@unza.zm or mundiamuya2000@yahoo.co.uk
[3]Lecturer; Department of Civil and Environmental Engineering; University of Zambia; P.O. Box 32379, Lusaka Zambia; Email: chabota.kaliba@gmail.com

and maintainable standards to facilitate connectivity, poverty alleviation, agricultural and marketing activities (RDA, 2008). GRZ's proactive initiatives were aimed at transforming Zambia into a truly land linked country in the Southern Africa sub-region (GRZ, 2010). Road infrastructure requires appropriate funding and good management to ensure maximum value is achieved. Inadequate levels of investment or poor management of the road network have serious consequences for economies and social well-being of citizens.

The major source of funding for infrastructure development in developing countries has been by Multilateral Development Banks (MDB).Without support from MDB or Cooperating Partners (CPs), projects in poorer, unstable or high-risk developing countries would often not get implemented. World Bank-financed projects result in 40,000 contracts being awarded annually and account for one third of total international contracts in developing countries (Hawley, 2004). Given their major role in financing and facilitating funding for infrastructure projects in low income countries such as Zambia, MDBs and CPs have a critical role to play in ensuring value for money (VfM). The concept of VfM is key in the use of public funds. In Zambia, public procurement is estimated at 10 percent of gross domestic product (GDP), and is therefore one of the top three types of spending besides salaries and debt re-payments. Assurance is required that public infrastructure is being purchased at the correct price, and not necessarily the lowest. The question is what is the correct price for one (1) km of a road? The prominence of VfM in the development agenda is that there is no fixed price of public infrastructure delivery. Two roads with exactly the same parameters built in the same geographical location will never have the same price. In fact, highway experts contend that the price of a road varies depending on the chainage from the project start point. However, assessing VfM is not a simple task in a developing country like Zambia because of limited standards, non-adherence to regulations and non-availability of reliable statistics. This is compounded by multiple stakeholders and their perspective of value for money. The National Audit Office (NAO) in the United Kingdom uses four criteria in assessing VfM of government spending (NAO, 2014):

a) economy (spending less);
b) efficiency (spending well);
c) effectiveness (spending wisely); and
d) equity (spending fairly).

From the four criteria, it is hoped that the Zambian road sector achieves VfM through efficient spending. While significant steps have taken place in recent years in ensuring VfM, serious vulnerabilities remain.

2. Literature Review

Project managers consider cost estimating to be an art (Vojinovic *et al.*, 2000). The accuracy of cost estimates is so important that a contingency for errors is incorporated in the estimate. However, Flyvbjerg (2006) stated that forecasts of cost, demand and other impacts of planned projects have remained consistently and remarkably inaccurate for decades. He further stated that inaccurate cost forecasts were a major source of risk to project management. Therefore accurate cost estimation has the potential to reduce project risk. The construction of a road is considered a long term project. Without accurate data, it is a daunting task to predict the future cost of goods and services. Inaccurate determination of cost escalation could result in non-viability of a project. Therefore, cost estimating is seen as one of the critical project success factors. It forms the basis for further planning and decision-making. By integrating cost estimation and cost control, the consequence of a failed or cancelled project is reduced.

2.1 Accurate Engineer's estimates

Cost estimation is essentially a computational process that attempts to predict the final cost of a future project, even though not all of the parameters and conditions are known when the estimate is prepared (AACE, 2013). The analysis of rates is a critical part of the project development process and when incorporated with quantities, provides the Engineer's estimate. The Engineer's estimate is important as it:

a) serves as a basis for probable construction cost;
b) supports decision-making on project scope; and
c) serves as a guide to evaluate bidders' proposals.

Confidence in the accuracy of the estimate should be established to make the Engineer's estimate an effective tool. Accurate cost prediction is perhaps one of the major requirements on any road construction project. A lack of understanding of the estimating process and cost control on road projects can result in under or over estimation. Estimating and bidding is not an exact science because of subjectivity from the estimator's experience, project scheduling, site supervision and productivity factors. In addition, the volatility of global prices such as those relating to oil based materials can adversely affect project cost estimates. Given the myriad of factors that affect cost estimation, it is important to understand them in order that some semblance of standardisation is obtained. Even though each project is unique, certain activities may be repetitive, similar or standard providing an opportunity for computer based cost estimation. This can be achieved through first principles estimating.

2.1.1 First principles estimating

The Oxford Advanced Learner's Dictionary (2014) defines first principles as the fundamental concepts or assumptions on which a theory, system, or method is based. A famous quote by Harrington Emerson (1911) states that "As to methods there may be a million and then some, but principles are few. The man who grasps principles can successfully select his own methods. The man who tries methods, ignoring principles, is sure to have trouble."

Estimating from first principles or cost based estimating is the preferred method for heavy highway-type bidding by contractors. Such estimates reflect the cost to construct the specified work in the most economical manner based on the contractor's capability and contract duration (Molenaar *et al.*, 2011). Estimating from first principles requires careful review of work crews and equipment completing tasks at assumed rates of productivity. Bid items are broken down into detailed task-by-task work activities. The direct cost for each task is developed with separate costs for the labour, equipment, subcontractor, and material components of the work required to complete a task (Molenaar *et al.*, 2011). By using the latest price data for materials, equipment and labour, an accurate estimate is produced unlike bid-based estimating that uses historical data. Since most contractors utilise this approach to prepare bids, it becomes advantageous to use the same estimating method to prepare an Engineer's estimates. Although more time and skill are required in first principles estimating compared to historical data based estimating, once the appropriate labour and equipment production data sources and material price database are created, the process is routine and manageable.

2.2 Contractor selection methods

In Zambia, industry regulators and public institutions have indicated that there was a notable trend in varying costs of construction from project to project and from one public institution to another, that it had become increasingly difficult to ascertain the true cost of projects and thereby unable to guarantee value for money (ZPPA, 2014). The traditional method of procurement is where the designer is responsible for design and the contractor for execution. Selection of a qualified contractor in the process of construction management is critical as contractors influence project success (Huang, 2011). The invitation of bidders to tender for construction works by the employer is to select the most responsive bidder in terms of cost and technical ability. There are various selection methods used in the construction industry. However, the study focuses on contractor selection using Least Cost Selection (LCS).

2.2.1 Least cost selection

In the case of the LCS, the selection is based on the lowest bid or "evaluated" price among those that achieved the stated minimum technical score. LCS for procurement of contracts is about comparative analysis and cost effectiveness. The utility industry which coined the term, has had tremendous success using its methods to identify the least expensive options for providing a finite amount of electricity to its customers. In the utility sector, LCS considers a wide variety of options from the demand as well as the supply side; from peak periods pricing to offering energy efficient light bulbs to customers for free or at a discounted price. As a result of this success, many have argued that the LCS criteria be translated for use in the road sector. However, this translation has proved difficult as tradeoffs in the road sector are more complex (HDR, 2010). In Ghana, like Zambia there is overwhelming acceptance to award construction projects to contractors who submit least cost bids. However, evidence suggests that this approach accounts for delay in projects, poor performance and project cost overruns (Oppong, 2013). Rather than automatically accepting the lowest price, the tender evaluation process should apply weighting factors for skills, quality, experience and previous performance in a manner to ensure value for money (Tasmania, 2014).

2.2.2 Best-value procurement method

Best-value procurement process is where price and other key factors are considered in the evaluation and selection process to minimize impacts and enhance the long-term performance and value of construction. Scott (2006) explains that best value may encompass the concepts from and variation of current highway procurement methods including prequalification, post qualification, A+B bidding, multi-parameter bidding, bid alternates and extended warranties. Scott (2006) further states that best-value procurement has been employed under traditional design and build contracting. In 2007, the Minnesota Legislature enacted a law that enables public agencies to select contractors based on best value, rather than low bid (MnDOT, 2012).

2.2.3 Weighted Criteria Procurement Method

The weighted method of tender evaluation requires that selection criteria, in addition to price, are included in tender documents and form part of the tender assessment process. A system of weighting the selection criteria is used to compare tenders and identify the tenderer with the best performance record in terms of time, cost and VfM (Akram and Zareba, 2012).

Construction procurement is often the subject of joint funding, with the different stakeholders having varying degrees of interest and objectives in the outcome of the project. Recent literature on this subject review that traditional processes of selection should be radically changed because they do not lead to best value and therefore the recommendation is that an integrated team, which includes the Client, should be formed before design and maintained throughout delivery (Akram and Zareba, 2012).The guide on better cost predictability in construction emphasises that current and accurate information should be shared between stakeholders.

3. Methodology

The results presented are from a broader study carried out on the analysis of unit rates for roadworks in Zambia. Data was collected using desk study and questionnaire survey. The desk study involved the review of 254 projects which were made available by the RDA. These projects were executed during a ten year period from 2005 to 2014. The research included the review of the contractor selection criteria in order to identify areas of migration from LCS to BVS in procurement of works. A total of 58 questionnaires were distributed to investigate the estimating methods used in the Zambian road sector.

The paper considers a combination of various aspects of the best-value procurement method and weighted criteria procurement method to result in the BVS which utilises the concept of VfM. The paper recommends BVS for adoption in the Zambian road sector.

4. Discussion of Findings

The desk study revealed that the traditional method of procurement is the most common in the Zambian road sector. The two most common types of selection methods in the Zambian road sector are: the Quality Cost Based Selection (QCBS); and the Least Cost Selection (LCS). In the Zambian road sector, QCBS, where bids are ranked according to their combined technical and financial scores, is applied to the selection of consultants. LCS is the method used to select a contractor.

Results from a questionnaire survey indicated that a limited number of construction personnel estimated from first principles. The findings showed that 27 percent of respondents built up rates from first principles compared to 55 percent who used historical rates. This could be attributed to lack of documented production rates and construction specific indices required for first principles estimates in the Zambian road sector. From literature, it was not clear which software was commonly used among contractors and practitioners in the Zambian road sector as no published research could be cited. The questionnaire survey findings indicated that only 4 percent of the respondents used software.

The desk review indicated that the current evaluation process in the Zambian road sector considers a preliminary, financial and post qualifying evaluation. BVS recommends cost, preliminary and project specific indicator evaluation.

4.1 Cost indicator

From literature, both the best value and weighted criteria procurement indicate cost as a major indicator. Therefore, BVS relies on an accurate Engineer’s estimate. One of the principles of obtaining VfM is openness and transparency. Therefore, the Engineer’s estimate for a project where bids are solicited should be known by all stakeholders. The Engineer’s estimate should be included in the advertisement and solicitation documents. Succeeding steps would be to only consider contractors whose bids are within ±25 percent. A difference of ±25 percent is selected because that is the acceptable standard percentage for variations to a project in the Zambian road sector.

The first step in BVS is evaluating bids by checking the correctness of the bill of quantities (BoQ) and verify that the total bid amount is within ±25 percent of the Engineer's estimate. The bid that is below but closest to the Engineer's estimate scores higher than a bid that is above but closest to the Engineer's estimate. The proposed ranking for the cost indicator is shown in Table 1. The table shows that where a number of bids have the same variance from the Engineer's estimate, the bid with a negative variance will be ranked higher than a bid with a positive acceptable variance.

Table 3: Proposed ranking of bids using BVS cost indicator

Bid variance from Engineer's estimate	Ranking
-5 %	1
+5 %	2
-10 %	3
+10 %	4
-15 %	5
+15 %	6
-20 %	7
+20 %	8
-25 %	9
+25 %	10

4.2 Preliminary indicators

After consideration of the cost indicator, preliminary indicators are then analysed. The basic requirements are assessed using the 'yes/no' criteria for items such as availability of contractor registration certificate in the right category and grade, power of attorney, bid security, site visit certificate and any other specified requirements. An example of preliminary indicator queries is shown in Table 2. From the table, BVS requires that all preliminary indicators are compliant. A 'NO' response to a preliminary indicator would affect the final VfM score.

Table 2: Preliminary indicator assessment (Source: adapted from RDA evaluation criteria)

	Preliminary indicators	Compliance (Yes / No)
1	Is the bid security amount indicated compliant?	
2	Is Bid Security Validity period in days compliant?	
3	Is Period of validity of the bid compliant?	
4	Is Power of Attorney compliant?	
5	Is Certificate of incorporation of firm valid?	
6	Have Names of Shareholders and Directors for a company and names of proprietors for a firm been indicated?	
7	Is NCC registration in grade and category valid and compliant?	
8	**Is there proof of Site Visit?**	

4.3 Project specific indicators

The last step in BVS is the project specific indicator (PSI) evaluation or detailed qualification. The PSI scored out of 100 include contractor general and specific experience, the company's financial status, subcontracting methodology, method statement, safety record, HIV awareness strategy, key personnel and equipment requirements. An example of project specific indicators is shown in Table 3. Details of PSI are specified in the bidding document. For instance, from Table 3 qualifications of a team leader may indicate PhD holder with 20 years experience in engineering. Bids with team leaders meeting that criterion would score 15. The total PSI score out of 100 is used to determine the VfM score.

Table 3: Project specific indicator assessment sheet (Source: adapted from RDA evaluation criteria)

	Project specific indicators (PSI)	Weight	Marks	Score
		A	**B**	**A x B**
1	**Specific Experience (10%)**			
	(a) Experience of the firm	4		0.00
	(b) Assignments of a similar nature	4		0.00
	(c) Experience in the Southern African Region	2		0.00
	Subtotal	**10**		**0**
2	**Adequacy of the proposed work plan and methodology in responding to the TOR (25%)**			
	(a)Technical Approach and Methodology	10		0.00
	(b) Work Plan	7.5		0.00
	(c) Personnel and Activity Schedules	7.5		0.00
	Subtotal	**25**		**0.00**
3	**Qualifications and competence of the key professional staff (55%)**			
	Team leader	**15**		**0.00**
	Pavement Engineer	**11**		**0.00**
	Traffic Engineer	**8**		**0.00**
	Transport Economist	**8**		**0.00**
	Surveyor	**7**		**0.00**
	Environmentalist	6		0.00
	Subtotal	**55**		
4	**Local Participation (6%)**			
	(a) Nationals among staff	3		
	(b) The firm	3		
	Subtotal	**6**		
5	**Training (4%)**	4		
6	**Total Score for each contractor**	**100.00**		**0.00**

4.4 VfM score calculation

The VfM score is then calculated by dividing the cost indicator by the PSI score. The bid with the lowest VfM score is the best value selected bidder. Comparison of the existing and proposed BVS process is shown in Figure 1.

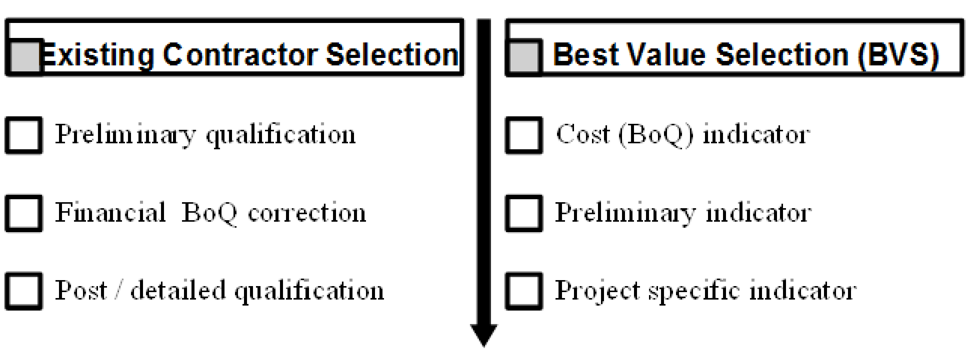


Figure 1: Comparison of existing and best value contractor selection process

4.5 Migration to BVS

The Engineer's estimate is paramount in BVS. Guidelines on awards or rejections of bids at a set level above the Engineer's estimate would have to be established. Therefore, migration to BVS would require laws or regulations regarding release or protection of the Engineer's estimate. This entails a standardised or uniform pricing mechanism to be put in place through development of a computer based unit cost estimation model. With the Engineer's estimate known, contractors can decide whether they would bid for the work or not at the onset.

Estimating in the Zambian road sector is carried out by a wide range of personnel who subscribe to protocols that are broadly understood, but are not consistently well documented. Desk study revealed that government units do not have primary basis for establishing estimated unit prices. In addition, the road sector estimating department does not have an official library for labour production rates, cost, tender, and construction material price indices. The government should therefore ensure that the estimating department denotes the primary basis for establishing estimated unit prices. The estimating department should also have an official road sector library with annual publications accessed online. There are various factors that affect construction costs in Zambia (Mwiya *et al.*, 2015). These factors depend on a country's political, economic, social and technological environment. The estimating department would ensure periodic review of identified cost factors. Guidelines in cases of poor competition or excessive difference between the estimate and the low bid have to be clearly spelt out. For instance, questions regarding adjustment of estimates after receipt of bids would be clarified. In BVS, due to transparency, pressure to award an apparently excessive bid will be eliminated.

5. Conclusion

The Government of the Republic of Zambia continues to invest in the construction of roads in all geographical regions of the country which have different topographical setups. The different regions have varied sources of materials and climatic conditions that may affect the pricing of road activities. Desk review of 254 projects reveals that the LCS method has been used for the past ten years from 2005 to 2014. But stakeholders perceive that Zambia does not always get value for money in infrastructure delivery. To achieve VfM in road infrastructure delivery, it is necessary to standardise cost estimation methods of road activities. By computing an accurate Engineer's estimates, the best value selection process can be used to achieve VfM.

6. References

AACE International (2013) *Cost Engineering Terminology, Recommended Practice No. 10S-90, TCM Framework: General Reference,* The Association for the Advancement of Cost Engineering (AACE)

Akram S. and Zareba K., (2012). *Strengthening of European Union Funds Absorption Capacity for infrastructure Construction Project* "Procurement Strategy in Construction". Warsaw, Ankara, Mondavio: s.n.

Flyvbjerg B. (2006) *From Nobel Prize to Project Management: Getting Risks Right*. *Project Management Journal*, vol. 37, no. 3, pp. 5-15

Government of the Republic of Zambia (GRZ), (2010), Sixth National Development Plan 2011 - 2015, Government printers, Zambia

HDR (2010). *History and Application of Least Cost Planning for Transportation from the Mid - 1990s.* Oregon: s.n.

Huang, X., (2011). *An Analysis of the selection of Project Contractor in the Construction Management Process. International Journal of Business Management*, Vol. 6(No. 3), p. 184.

Molenaar K., Stuart A., and Clifford S. (2011) *AASHTO Practical Guide to Estimating*, National Cooperative Highway Research Program (NCHRP) Project 20-07/Tasks 278 and 308

Mwiya B., (2016) *An Analysis of Unit Rates for Roadworks in Zambia incorporating Neural Network Prediction and First Principles Estimating*, Unpublished thesis, University of Zambia

Mwiya B., Muya, M., Kaliba, C. and Mukalula, P. (2015), *Construction Unit Rate Factor Modelling Using Neural Networks,* World Academy of Science, Engineering and Technology, International Science Index 97, ISSN: 1307-6892 International Journal of Civil, Architectural, Structural and Construction Engineering, 9(1), 29 - 34.

Oxford Advanced Learner's Dictionary 9th Edition (2014) Oxford University Press ISBN-13: 978-0194799485

Road Development Agency (RDA) (2008) Second Quarterly Report (01 April – 30 June 2008), RDA

Scott S. (2006) *Best-value Procurement Methods for Highway Construction Projects*, Issue 561 of National Cooperative Highway Research Program (NCHRP) report, Transportation Research Board, ISBN 0309098580, 9780309098588

Vojinovic Z., Rainer S., and Vojislav K. (2000) *Advanced Cost Estimating and Strategic Planning,* AACE International Transactions. Morgantown, WV: AACE International

Zambia Public Procurement Authority (ZPPA) (2014) *Consulting services to undertake an assessment of the prevailing market rates in the construction industry*, Request for proposals, ZPPA, Zambia

Proceedings of the DII-2014 Conference
on Infrastructure Investments in Africa

25-26 September 2014
Livingstone, Zambia
ISBN 978-0-86970-782-1

DII-2014-001

FACTORS AFFECTING CONSTRUCTION UNIT RATES IN THE ZAMBIAN ROAD SECTOR

Balimu Mwiya[1], Mundia Muya[2], Chabota Kaliba[3] and Peter Mukalula[4]

Abstract

It is perceived by stakeholders that Zambia does not always get value for money in infrastructure delivery. Industry regulators and public institutions have indicated that there was a notable trend in varying costs of construction from project to project and from one public institution to another, that it had become increasingly difficult to ascertain the true cost of projects and thereby unable to guarantee value for money (ZPPA, 2014). The national roads system in Zambia is experiencing a period of exceptional activity following large increase in public spending in the sector to improve and enhance efficiency of transport infrastructure. It is therefore important for key stakeholders to have an informed decision on prevailing market rates and how they are determined.

The main objective of the study was to investigate the difference between actual direct costs and prevailing market rates in infrastructure delivery. This difference referred to as the 'economic strata' or 'cost structure' reflects the peculiarities of the local setting usually qualitative in nature such as prevailing project conditions, competition and other risk factors.

The study reported in this paper was aimed at selecting and assessing factors that account for cost variations across road construction projects in Zambia to be incorporated into a Unit Cost Estimation Model (UCEM). Through expert interviews, it was established that major cost factors in road construction were mainly due to location, haulage distance, delayed payments and quality of project management. Of interest were factors such as political risk, advance payment and type of project consultant that were anticipated to have a major effect but which results revealed had little or no effect.

Key words: construction unit rates, unit cost estimation model, road works, cost factors, Zambian construction industry

[1] PhD Student; Department of Civil and Environmental Engineering; University of Zambia; P.O. Box 32379, Lusaka, Zambia; Email: mwiyab49@gmail.com
[2] Dean, School of Engineering, University of Zambia, P.O. Box 32379, Lusaka, Zambia. E-mail: mmuya@unza.zm
[3] Lecturer; Department of Civil and Environmental Engineering, University of Zambia, P.O. Box 32379, Lusaka Zambia. Email: cjicax@yahoo.co.uk
[4]PhD Student; Department of Civil and Environmental Engineering; University of Zambia; P.O. Box 32379, Lusaka, Zambia; Email: musomuko@yahoo.com

25-26 September 2014
Livingstone, Zambia
ISBN 978-0-86970-782-1

Understanding cost factors is the first step in the development of a UCEM that can be used in determining the make-up of prevailing market rates thus addressing Zambia's perceived high infrastructure costs.

1.0 Introduction

It is perceived by stakeholders that Zambia does not always get value for money in infrastructure delivery. Major stakeholders such as the National Council for Construction (NCC), the Zambia Public Procurement Authority (ZPPA), the National Road Fund Agency (NRFA) and the Road Development Agency (RDA) have in the recent past called for an informed position on prevailing market rates in the Zambian construction industry. ZPPA (2014) stated that there was a notable trend in varying costs of construction from project to project and from one public institution to another, that it had become increasingly difficult to ascertain the true cost of projects and thereby unable to guarantee value for money. NCC (2010) stated that it was understandable for rates to rise as certain costs such fuels and other inputs that go into construction works rise, however the rise in the costs had been too drastic for the Zambian industry. In the absence of construction indices, there was need to establish guidelines on factors that influence the determination of rates in the Zambian construction industry.

The national roads system in Zambia is experiencing a period of exceptional activity following large increase in public spending in the sector to improve and enhance efficiency of transport infrastructure. In September 2012, Zambia made her inaugural entry on the international capital market and raised US $750 million, at a price that is one of the lowest ever for a debut issue for a Sub-Sahara African country. US $430 million (57%) of the Eurobond was budgeted for road and rail transport (GRZ, 2013).

Though the underlying production technology of road construction is similar, the cost structure of the services varies. To understand whether the existing road sector is operating efficiently and whether it can handle the rising changes successfully, there was need for the RDA as custodian of roads in Zambia to appreciate the cost structure of the industry. Malmsten (2008) stated that to capture the cost structure of an industry is not necessarily the same as to capture the actual costs raised by the system. The difference between actual direct costs and prevailing market cost is referred to as the "economic strata".

This paper identifies cost factors to be used to measure the "monetary behaviours" of cost estimation in infrastructure delivery. Roughly determining the economic strata of a process involves understanding the unit costs of the whole process, and characterizing how resources are allocated and how they scale with size of the task. Though factors that affect road construction cost are more or less the same worldwide, it is the impact or effect that varies and makes it unique to a particular sector or country. It is therefore imperative that the economic strata of a system be analysed in order to assess efficiencies and inefficiencies in the system.

ISBN 978-0-86970-782-1

2.0 Literature review

Cost estimating is essentially a computational process that attempts to predict the final cost of a future project, even though not all of the parameters and conditions are known when the cost estimate is prepared (AACE, 2013). In general, estimating methods vary considerably, depending upon the available information, the nature of the project, and the time available to prepare the estimate. The most common approach to cost estimation used in Zambia is unit costs for bill of quantities. Hendrickson (2008) describes the unit cost estimation approach as, where a unit cost is assigned to each task as represented by the bill of quantities and the total cost is the summation of the products of the quantities multiplied by the corresponding unit costs. A study carried out by Mashilipa (2004) investigated various cost estimation methods used in the Zambia construction industry. It revealed that the most common method was the use of rates based on past contracts with an allowance for inflation followed by building up of unit rates from first principles and finally use of computer software. Mashilipa (2004) observed that use of previous tender rates was common because of lack of experienced cost estimators in the bidding firms and the reduced duration of coming up with an estimate. This trend in Zambia indicated that estimate accuracy was the least requirement by the bidders. This was further compounded by the fact that the Surveyors Institute of Zambia does not have guidelines on cost estimate accuracy as established by professional quantity surveying bodies in other countries.

The consequences of an ill-defined cost estimation system is demonstrated below in a project carried out in 2011 involving 31.1 Km of urban roads on the Copperbelt, Zambia known as the Formula 1 Lot 4. Summary of the bids received is shown in Table 1.

Table 1: Formula 1 Lot 4 Bid Summary

S/No.	Name	Total sum in ZMW	Project rate per km
1.	Contractor A	75,623,454.16	2,431,622.32
2.	Contractor B	89,723,044.16	2,884,985.34
3.	Contractor C	198,509,008.27	6,382,926.31

It was astounding that the difference in bids was as high as 162%. Even the second lowest bidder was 16% above the lowest bidder. Further examination of the unit prices for different work items revealed even larger disparities of around 2000%. Table 2 shows unit rates for selected items that showed huge disparities.

ISBN 978-0-86970-782-1

Table 2: Unit Prices with huge disparities in Formula 1 Lot 4 Bids

S/No	Description	Unit	Rate 'ZMW		
			A	B	C
1.	150mm compacted pavement layer	m3	45.76	105.00	147.00
2.	crushed stone base	m3	10.00	222.50	36.75
3.	road-marking: white lines	Km	2,788.50	8,866.50	14,700.00

A review of literature showed that there was no single approach to developing construction unit rates (CUR). Generally, road construction works can be considered as a combination of two types of items. Firstly, those that can be estimated through some form of calculation, for example, the direct labour, material and equipment inputs. In this category the cost relationships between labour, material and plant are known. Secondly, items cannot be calculated directly. The difference between actual direct costs and prevailing market rates is referred to as the 'economic strata' or 'cost structure' which reflects the peculiarities of the local setting usually qualitative in nature such as prevailing project conditions, competition and other risk factors.

Study focus

Central parameters + economic strata = prevailing market rates

Formula 1: Mathematical representation of area of study

There are various unit rate build up software available which accurately estimate the direct costs and usually allow a percentage mark-up to accommodate the economic strata.

The study focuses on understanding the factors that make up the economic strata of road works in Zambia. Blocher et al. (2008) stated that in cost estimation choosing cost drivers was the most important step since the model's accuracy was based upon selecting the relevant and appropriate cost drivers. Literature identifies various factors that affect construction cost with varying impacts in different parts of the world. Table 3 summarises some of the top ten factors influencing cost estimation in different countries.

25-26 September 2014
Livingstone, Zambia
ISBN 978-0-86970-782-1

Table 3: Top ten factors influencing cost estimation in different countries.

Author	Enshassi et al. (2007)	Memon et al. (2010)	Elinwa AU and Buba SA. (1993)	Trombka Aron and Sarah Downey (2008)
Title	Contractors' Perspectives towards Factors Affecting Cost Estimation in Palestine	Factors Affecting Construction Cost Performance in Project Management Projects: Case of Mara Large Projects (Malaysia)	Construction cost factors in Nigeria	A Study of County Road Project Cost and Schedule Estimates
Factors	1. Location of project (hot areas) 2. Segmentation of Gaza strip 3. Closure of Gaza strip 4. Financial status of the owner 5. Increase in unit costs of construction materials 6. Experience of consultant engineer 7. Clarity and quality of drawings before tendering 8. Clarity and accuracy of information related to the project before execution 9. Number and classification of competitors in tendering 10. Tender's currency	1. Fluctuation in prices of materials 2. Cash flow and financial difficulties faced by contractors 3.Shortage of site workers 4. Lack of communication among parties 5. Incorrect planning and scheduling by contractors 6. Contractor's poor site management and supervision 7. Delay in Material procurement 8. Underestimate project duration resulting Schedule Delay 9. Unforeseen ground conditions 10. Low speed of decisions making	1. shortage of materials 2. financing methods and payments for completed works 3.poor contract management, 4. materials cost 5. fraudulent practices and kickbacks 6. the fluctuation of material prices	1. Project Scope: 2. Land Acquisition: 3. Utility Relocation: 4. Laws, Regulations, and Policies 5. Environmental Compliance: 6. Surrounding Development: 7. Nearby Road Projects: 8. Cost Increases/Inflation: 9. Fiscal Conditions: 10. Procurement Process:

From Table 3, the factors reveal an insight into the construction economic strata of the different countries. In Palestine, closure and blockade of borders indicate security concerns contractors experience where as in the United States of America utility relocation is a major factor due to the developed nature of the country. Whereas fluctuation in prices of materials is a major factor in Malaysia, it is the shortage of materials that affect construction cost the most in Nigeria. In

ISBN 978-0-86970-782-1

addition, the inclusion of corruption as a factor in indicates an issue contractors have to deal with in Nigeria.

It can be deduced from literature that periodic review of cost factors was essential because of countries constant political, economic social and technological transformation.

The determination of cost factors in the Zambian road sector forms the basis of the UCEM to be developed using neural networks (NN). Though there is no limit on the number of factors or variables to be used in NN, Bode (1999) stated that the number of attributes assumed to have an effect on cost should be small because the architectural complexity increases with the number of attributes, requiring more training samples to reach a given accuracy, yet training samples were usually scarce in cost estimation. From literature review, the number of influencing factors used in similar studies in NN is indicated in Table 4. Table 4 indicates an average of 9.9 factors.

Table 4: Number of input cost factors for Neural Networks

S/No.	Author	Topic	Number of cost factors used
1.	Peško et al., 2013	A preliminary estimate of time and cost in urban road construction using neural networks	9
2.	Hasan Abu Jamous (2013)	Parametric Cost Estimation of Road Projects Using Artificial Neural Networks	9
3.	Muqeem et al., 2011	Construction labour production rates modelling using artificial neural network	5
4.	Krzysztof Schabowicz & Bozena Hola (2007)	Mathematical-neural model for assessing productivity of earthmoving machinery	5
5.	Emsley et al., 2002	Data modelling and the application of a neural network approach to the prediction of total construction costs	Network 1 – 5 Network 2 – 9 Network 3 – 41
6.	Hashem Al-Tabtabai et al., 1999	Preliminary cost estimation of highway construction using neural networks	9
7.	Moselhi and Siqueira, 1998	Neural networks for cost estimating of structural steel buildings	4
8.	Ayed, 1997	Parametric cost estimating of highway projects using neural networks	10
9.	Creese and Li, 1995	Cost estimation of timber bridges using neural networks	3

ISBN 978-0-86970-782-1

From literature review, cost factors which affect unit costs were selected and divided into four categories country, road sector, contractor and project specific as presented in Table 5.

Table 5: Selected cost factors from literature review

Country specific: (for comparison with other countries) Country classification, Human Development Index (HDI), The Global competitive index (GCI), Ease of doing business, Corruption Perception Index, Gross Domestic Product, Total road network (km), Road density (km of road per 100 sq. km of land area), Total % of paved roads
Road Sector specific: (includes regulations and policies imposed by road sector regulators) Land acquisition, Project need, delayed payment, Contract financing or financial assessment, political risk, advance payment provisions, 20% subcontracting, HIV training, project consultant, Project planning and management, quality of bidding documents, Price adjustment clause, Contractor selection method, Road type, Exchange rate, Material shortages, Material Source, Competition, environmental (EIA) project site restoration,
Contractor Specific: Contractor size, Contractor type, Labour, Equipment availability, contractor cash flow, Overhead & Profit
Project Specific: road length, Duration, Year, Project scope, Culvert crossings, Location, Hauling distance, Detour, Utilities, Soil condition, Climate,

3.0 Methodology

The research methodology in the reported study evolved around the need to establish the cost factors to be incorporated in the UCEM. From literature review various factors that influence unit rates in road works were identified. In all previous studies, the selection of cost factors was dependant on the experience and expertise of industry professionals. A number of techniques were available to acquire tacit knowledge based on the expertise of construction specialists such as Delphi, nominal group technique and or expert interviews.

In a study by Hashem Al- Tabtabai et al. (1999), factors were selected based on interviews by five 5 industry experts. Interviews were adopted as a means of data collection. Structured interviews were conducted between February and May 2014. The interviews targeted ten professionals comprising five civil engineers and five quantity surveyors with experience in costing of road works in Zambia.

4.0 Survey results

4.1 Profiles of interviewees and their firms

Seven out of the targeted ten professionals participated in the interviews. Out of the seven interviewees, five had over twenty years of experience in infrastructure estimating while the other two interviewees had between ten and fifteen years of experience. All interviewees held management positions within their organisations.

ISBN 978-0-86970-782-1

4.2 Influencing factors

Interviewees were asked questions regarding the impact of cost factors on unit rates based on the Likert scale of 1 to 5 where 1 means no impact and 5 means extremely high impact. Analysis was done using SPSS. The factor analysis could not be used as the dataset of seven interviewees was too small. Analysis using descriptive statistics was adopted. The sum and mean statistics were used to categorise factors in quartiles as shown in Table 6, where the first quartile represented factors with the highest impact and those with the lowest influence in the fourth quartile.

Table 6: Ranking of cost factors categorised in quartiles

1st quartile: location hauling distance Delayed payment Project planning and management Material Source Equipment availability Project need Exchange Rate Contractor type duration Project scope	**2nd quartile:** detour Contract financing labour contractor cash flow political risk soil type contractor selection method Material Shortages Contractor size Overhead & Profit Corruption Perception Index
3rd quartile: Quality of bidding documents utilities Culvert Crossing climate Ease of doing business Price adjustment clause Country classification The Global competitive index Land acquisition Road Type Competition	**4th quartile:** Road length Gross Domestic Product Total road network Advance payment Human Development Index environmental (EIA) project site restoration, Project Consultant Total % of paved roads year 20% subcontracting HIV training, Road Density

5.0 Findings

5.1 Location

All interviewees agreed that location was a major factor in bidding for contracts. Further query from an interviewee revealed that mobilisation costs were about 10% higher for areas such as Shangombo which is close to 900 kilometres from Lusaka and considered as one of the remotest areas of Zambia.

ISBN 978-0-86970-782-1

5.2 Haulage distance

Once again all the interviewees agreed that hauling distance in transporting material and equipment had a high impact on cost. In fact five of the seven interviewees emphasised that as such fuel should be included as a separate factor.

5.3 Delayed payments

Interviewees bemoaned the continued occurrence of delayed payments in the road sector. It was agreed that stakeholders did factor potential delays in payment into their pricing of contracts. Apart from delays resulting in slowing down or suspension of ongoing works, three interviewees felt that this led to fraudulent activities in the sector.

5.4 Project planning and management

Inclusion of project planning and management as a high impact cost factor gave an insight into the operations of the road sector in Zambia. Interviewees felt that issues that led to the increase of cost due to this factor included: the practice of appointing supervision consultants after appointing the main contractor; procuring works without sufficient budget allocations; incomplete or uncoordinated bid documents calling for more addenda during tendering; proceeding with projects before they are well defined; improper use and calculation of contingencies; lack of engineer's estimates; and absence of appropriate economic models in the estimating process.

5.5 Foreign exchange rate

Only two out of the seven interviewees stated that the inflation rate should be used as opposed to the exchange rate. Though all payments on road contracts were made in Zambian Kwacha with a price adjustment clause to contracts longer than 18 months, the remaining interviewees stated that the exchange rate was appropriate because road contracts had high import content of input costs such as bitumen, equipment purchase and associated maintenance cost (spare parts), steel reinforcement and fuel. One interviewee went on to state that the percentage of fuel increase could be used as a unit cost index.

5.6 Other anticipated factors

It was interesting to note that political risk and corruption were not major factors as anticipated because in 2011, the Government of the Republic of Zambia placed the road sector under the auspices of the president's office reporting directly to the head of state. It was felt that this would increase the political risk profile of the construction industry.

The interviews further revealed that advance payment, the type of project consultant and competition had minimal influence on prevailing market rates contrary to the previous study conducted by RDA (2009) which indicated that:

ISBN 978-0-86970-782-1

- when advance payments were removed from Government construction contracts in 2008, the impact on contractors' prices was significant as the cost of borrowing in Zambia was high. However, interviewees felt the position was different today;

- knowing the supervising consultants was important though the impact was not stated. The interviewees felt this had minimal effect; and

- lack of competition was a factor increasing rates on larger contracts, particularly since 2008 because when competition was reduced and a large number of contracts are tendered, as in 2008, contractors tended to increase their prices.

During the interviews additional factors were highlighted. Though energy costs were included as part of plant and equipment productivity, it was emphasised that energy costs such as fuel should be a stand-alone item. It was recommended that soil and climate factors be combined and renamed as topography – terrain. Other factors were contractor work conditions, inflation, funding source, design criteria such as number of lanes, pavement layer and base material. Four out of the seven interviewees argued that the project scope or design criteria could not be a factor as that was part of actual costs of construction. Under country specific factors one interviewee felt that a country's stability contributed to unit costs. Generally, all factors that were included under the contractor specific category scored high on the ranking implying that any changes on unit costs would have to target the contractor.

In summary, the Zambian road economic strata revealed that contractors have to deal with delayed payments in the sector, long haulage distances and questionable project planning and management by public sector clientele institutions. The selected factors in the first, second quartile and additional factors will be further investigated through a questionnaire survey.

6.0 Conclusions

Reviewed literature indicated that the influencing cost factors reveal an insight into the construction economic strata of a country. Overtime, it was likely that the influencing cost factors would change depending on the country's political, economic social and technological transformation. Therefore it would be prudent to investigate the said cost factors periodically.

Initial desk study revealed that there was a variation of more than 160% - 2000% in unit costs among bidders indicating an area of concern amongst stakeholders in the Zambian road sector. Preliminary interview results showed that factors that influence cost in the Zambian construction industry include location, haulage distance, delayed payments and quality of the sector's project management. From the country's perspective some of the unexpected results were the political risk, corruption, advance payment, prior knowledge of supervising consultants and competition which were expected to feature in the first quartile but were in the lower quartiles. In summary, the Zambian road economic strata revealed that contractors have to deal with delayed

ISBN 978-0-86970-782-1

payments in the sector, long haulage distances and questionable project planning and management from public clientele institutions.

References

AACE International (2013), Cost Engineering Terminology, Recommended Practice No. 10S-90, TCM Framework: General Reference, The Association for the Advancement of Cost Engineering (AACE)

Adnan, E., Mohamed, S and Madi, I., (2007), Contractors' Perspectives towards Factors Affecting Cost Estimation in Palestine. Jordan Journal of Civil Engineering, 1 (2) 186-193.

Aron, T., and Downey, S., (2008) A Study of County Road Project Cost and Schedule Estimates, Office of Legislative Oversight, Montgomery County, Maryland Report Number 2008-04 (available online https://www.montgomerycountymd.gov/olo/resources/files/2008-4.pdf [accessed 05/07/2014])

Ayed A. S., (1997), Parametric Cost Estimating of Highway Projects using Neural Networks, MEng Unpublished thesis, Memorial University of Newfoundland, Canada

Blocher Edward J. David E. Stout Gary Cokins Kung H. Chen (2008), Cost management; A strategic emphasis 4th ed., McGraw Hill

Bode, J. (1998), Neural Networks for Cost Estimation, Cost Engineering Journal 40 (1) 25-30

Creese R. and Li, (1995), Cost estimation of timber bridges using neural networks, Cost Engineering Journal Vol. 37(5)

Elinwa, A.U. and Buba, S.A. (1993), Construction cost factors in Nigeria, Journal of Construction Engineering and Management. 119 (4), 698-713.

Emsley, W.M., Lowe, J.D., Duff, A.R., Harding, A., and Hickson, A., (2002), Data modelling and the application of a neural network approach to the prediction of total construction costs; Construction Management and Economics (20) p. 465–472 (available online http://www.tandf.co.uk/journals DOI: 10.1080/01446190210151050 [accessed 16/01/2014]

Government of the Republic of Zambia (GRZ), (2012), *GRZ Budget 2013*, Government printers, Zambia

Hameed, A.M., Rahman, A.I., Abdullah, R.M., Azis, A.A.A., (2010) "Factors Affecting Construction Cost Performance in Project Management Projects: Case of Mara Large Projects".

Proceedings of Post Graduate seminar on Engineering, Technology and Social Science. 29-30 November 2010, Universiti Tun Hussein Onn Malaysia

Hasan, A. J., (2013) Parametric Cost Estimation of Road Projects Using Artificial Neural Networks, M.Sc. Unpublished thesis, The Islamic University, Gaza

Hashem Al-Tabtabai, Alex P. Alex, and Maha Tantash. (1999) Preliminary Cost Estimation of Highway Construction Using Neural Networks, Cost Engineering 41, (3) 19-24

Hendrickson, C. (2008), Project Management for Construction, Fundamental Concepts for Owners, Engineers, Architects and Builders (available online: http://pmbook.ce.cmu.edu/ accessed [05/11/2013])

Igor, P., Trivunić, M., Cirović, G., and Mučenski, V., (2013), A preliminary estimate of time and cost in urban road construction using neural networks Technical Gazette 20 (3), 563-570 [accessed 16/01/2014]

Malmsten, M., (2008), Production cost structure of the water and sewage industry. An econometric cost analysis of urban water supply and sewage treatment, with an application to a section of Swedish communities (available online https://www.kth.se/polopoly_fs/1.175009!/Menu/general/column-content/attachment/2008_64.pdf [accessed on 11/11/2010])

Mashilipa, J., (2004), An investigation on the effects and their implications of using British outputs in Estimating in the Zambian Construction Industry, BSc (Building) Unpublished thesis, Copperbelt University, Zambia

Moselhi, O., and I. Siqueira (1998) Neural Networks for Cost Estimating of Structural Steel Buildings. AACE International Transactions.

NCC (2010) Unit Rates in the Zambian Construction Industry, Construction News issue 3 p1,3

RDA (2009) Cost Based Unit Rate Analysis and Design Review of District Roads Projects in Luapula and Western Provinces of Zambia UNIT RATE ANALYSIS REPORT DRAFT-2, RDA

Sana, M., Idrus, A., Khamidi, M.F., Ahmad, B,J., Zakaria, B.S., (2011) Construction labour production rates modelling using artificial neural network, Journal of Information Technology in Construction (ITcon), Vol. 16, pg. 713-726, (available online http://www.itcon.org/2011/42 [accessed on 09/04/2014])

ISBN 978-0-86970-782-1

Schabowicz, K., & Hola, B., (2007), Mathematical-neural model for assessing productivity of earthmoving machinery, Journal of Civil Engineering and Management, 13:1, 47-54 (available online http://dx.doi.org/10.1080/13923730.2007.9636418 [accessed 16/01/2014])

ZPPA (2014) Consulting services to undertake an assessment of the prevailing market rates in the construction industry, Request for proposals, ZPPA, Zambia