CONCEPTUAL COST ESTIMATION OF ROAD PROJECTS IN ETHIOPIA USING NEURAL NETWORKS

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ABSTRACT

The rapid technological changes and advances in all business sectors strongly impose construction managers to facilitate their work through advanced software applications available to simplify different tasks. A research has shown that inaccurate cost estimation method is among the cause of cost overrun in the Ethiopian construction industry. This article presents conceptual cost estimation model developed using neural networks for federal road projects of Ethiopia. The conceptual cost estimation model developed has a mean absolute percentage error of 32.58% trained with only 48 exemplars. If the model is developed with the provision of enough data set to represent the road project with all-state of affairs, it is forecasted to improve the estimating capability of financers, employers and consultants. In addition, a friendly user interface is built to enable the utilization of the model developed easily and this article presents this interface with an example of actual road project in Ethiopia. The findings of this study indicate the prospect of application of neural network for cost estimation during early phase of the project development for Ethiopian road projects.

Key Words: Conceptual Cost Estimation, Neural Network, Parameters, Reliable estimate

INTRODUCTION

Reliable cost estimates are necessary for responsible cost management at every stage of a project. The application of advanced conceptual cost estimation tools in Ethiopian Construction industry is at an infant stage and requires localized researches. Cost overrun of infrastructure projects has become a common problem for the construction industry as recognized by industry researchers and practitioners [1].

The higher amount of budget allocated to the road construction industry stresses the requirement of applying advanced planning tools for project completion within estimated cost.

The Government of Ethiopia formulated the Road Sector Development Program (RSDP I to IV) in 1997 and disbursed 48.11 Billion Birr in the years 2011 and 2012 for the RSDP IV [2]. A research conducted by ERA Research Center on causes of cost overrun on Ethiopian Federal Road projects in 2016 showed that 10 to 21% of cost overrun is recorded [3]. This shows the requirement of measurement to be taken to improve cost estimate reliability.

A research revealed that inaccurate cost estimation method and poor planning are among the factors contributing to cost overrun in the Ethiopian construction industry [4].

In addition, the review of best practice, which is the research conducted by U.S. department of transportation Federal highway administration, showed that cost estimation programs and quality control & assurance programs are developed in light of addressing cost overrun issues [1].

This paper aims to use a similar approach and develop a conceptual cost estimation model for Ethiopian road projects through the application of Neural Network. Therefore, identification of factors that affect total cost, which are to be used as parameters in training a Neural Network model, is the first objective.

The chief goal is to support decision makers through increased reliability of estimated cost of road construction projects at early stages of project development by providing cost estimation tool.

LITERATURE REVIEW

Conceptual Cost Estimation

A conceptual estimate is made during early phase of project development without detailed design and engineering data, and with limited information on project scope. Therefore, considerable experience and judgment are required to obtain a dependable approximate estimate for the cost.

Estimating is the heart of the cost engineer's work and consequently, it has received appropriate attention over the years. The first function of a conceptual estimate is to tell the owner about the anticipated cost, thus presenting useful information for the owner in contemplating the project feasibility and further development [6]. Conceptual and preliminary estimates are made for several reasons, including [7] [8]:

- Feasibility studies
- To establish a basis for financing, appropriation of funds or validation of project budgets
- Appropriation of the project scope and selection from alternate design and investment
- Presentation of bids and tenders which is to establish a benchmark for a construction bid

Cost Estimating Methods

Cost Estimating methodologies fall into one of the following four categories discussed below [5].

Historical bid-based Estimation

Historical bid-based methods are commonly used to develop engineer's estimates, and are applied when the project design progressed enough to provide quantities of unit of works. Historical unit costs are applied to estimate the total cost of each work items [5].

Cost based Estimation

Cost-based estimate methods are based on calculation of unit costs for each project with details of labor, equipment, material and specialty contractor estimation for each item of work. Historical bid data are not utilized [5]. Cost-based estimates require significant effort, time, and estimator experience to prepare.

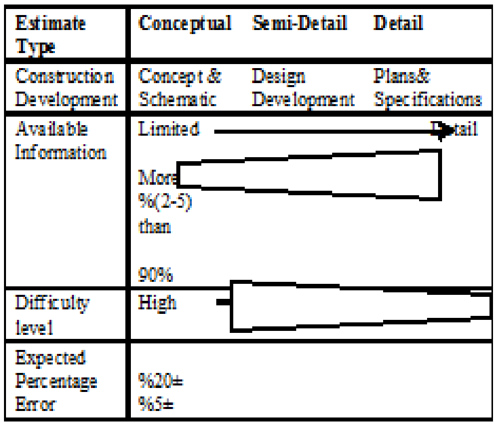

Fig.1: Construction cost estimating methods [9]

They should be limited to those items that comprise the largest cost percentage of the project, typically that 20% of items of work that account for 80% of project cost. The cost of the remainder of estimate line items can be determined using Historical Bid-Based Estimate methods [11].

Risk-based

Risk-based estimate methods include complex probabilistic analysis with identification of opportunities and threats related to cost, schedule, and events related to the project. It uses different techniques, such as historical data, cost based estimating, and the best judgment of subject matter experts for given types of work [5].

Information Available during Conceptual Project Development Level

The information available is one of the distinctive features of the different types of cost estimates. The estimate level among the different types of estimates available does not give clear and definite boundary. Due to this reason, there are some literatures that use the terms conceptual and preliminary estimate interchangeably. During the conceptual phase, general information about the project will be available such as the road length, road width from standards, the location of the project and the project scope.

And a parametric cost estimation technique can be deployed from historical costs of similar past projects. During the preliminary phase, preliminary quantities of earthwork and pavements are available by the use of digital terrain model and different maps. Figure 1 below shows the available information, difficulty level and expected percentage error for different types of cost estimates.

The identification of the influential factors or parameters affecting total project construction cost is necessary to develop cost estimating model. The input parameters identified through literature review of road construction cost estimation are summarized below in table 1.

Artificial Neural Network

Artificial intelligence is defined as: "The study of how to make computers do things at which, at the moment, people are better" Rich and Knight, 1991

Artificial Intelligence is the branch of computer science that is concerned with the automation of intelligent behavior and seeks to explain and emulate intelligent behavior in terms of computational processes [15]. Artificial Neural Networks (ANNs) are a functional abstraction of the biologic neural structures of the central nervous system [16].ANN generally learns from "experience", rather than being explicitly "programmed" with rules like in conventional artificial intelligence [17].

Benefits and limitations of Artificial Neural Network

The use of neural networks offers the following useful properties and capabilities [18]:

Input-output mapping: a popular paradigm of learning called supervised learning involves the modification of the synaptic weights (free parameters) of a neural network by applying a set of training samples. Thus the network learns from the samples by constructing an input-output mapping for the problem at hand.

Adaptive: Neural networks have a built-in capability to adapt their synaptic weights to changes in the surrounding environment.

i. Contextual information: contextual information is dealt with naturally by a neural network.

ii. Fault tolerance: a neural network has the potential to be inherently fault tolerant.

- To predict acceptability of a new technology, cash flow, construction demand, construction budget performance and construction cost
- To investigated the overhead cost practices of construction companies in Saudi Arabia
- To develop cost estimating model for the structural systems of reinforced concrete buildings in the sense that its performance is degraded gracefully under adverse operating. Although the artificial neural networks have many advantages, on the other hand their accuracy highly depends on the quality of the trained data and the ability of the developer to choose truly representative sample inputs. In addition, trial and error method used to obtain the formula to decide what architecture of ANN should be used to solve the given problem and which training algorithm to use.

Application of ANNs in Construction Engineering

The most common application of ANNs in the construction management area is prediction. Few of the applications of the ANN in construction management for prediction and estimation in construction engineering are given below [9, 16]:

- Model for predicting increase in time and cost of construction projects in Egypt
- To forecast actual cost of a project based on the earned value management system
- To estimate conceptual cost of Libyan Highway Projects

The literatures show the vast application of ANN in the construction industry worldwide and the need of the Ethiopian construction industry to advance in order to cope up with the rapid and dynamic advancement of technology is undeniable.

Table 1: Previously used parameters by other research papers [9, 12, 13, 14]

Year	Research description	Input parameters
1998	Neural network approach was used to determine highway construction cost in Canada	Project type, project scope, year, construction season, location, duration, size, capacity, water body, and soil condition.
2005	Multiple regression model and ANN model were used to estimate the cost at conceptual phase of highway projects in Poland and Thailand.	Predominant Work Activity (Asphalt or Concrete), Work Duration, Pavement Width, Shoulder Width, Ground Rise Fall, Average Site Clear/Grub, Earthwork Volume, Surface Class (Asphalt or Concrete), and Base Material (Crushed Stone or Cement Stab).
2013	Parametric Cost Estimation of Road Projects Using Artificial Neural Networks in Palestine	Project scope, Water networks, Pavement type (asphalt or interlock), Pavement area, Length of the road, Length of the curbstones Lighting networks, Sewage networks
2013	Conceptual Cost Estimate of Road Construction Projects in Saudi Arabia by developing regression models to predict the total construction cost of a road project in the early phases.	Earthwork; cut and fill (m3), Base works (m2), Asphalt works (m2), Road length, Road width (m)
2014	Testing regression models to estimate costs of road construction projects, to develop early cost estimating models of road construction projects in Ethiopia	Earthwork; cut, fill, and topping quantities (m3), Sub base and Base coarse quantity (m3), Asphalt quantity (m2), Road width (m), Road length (m)

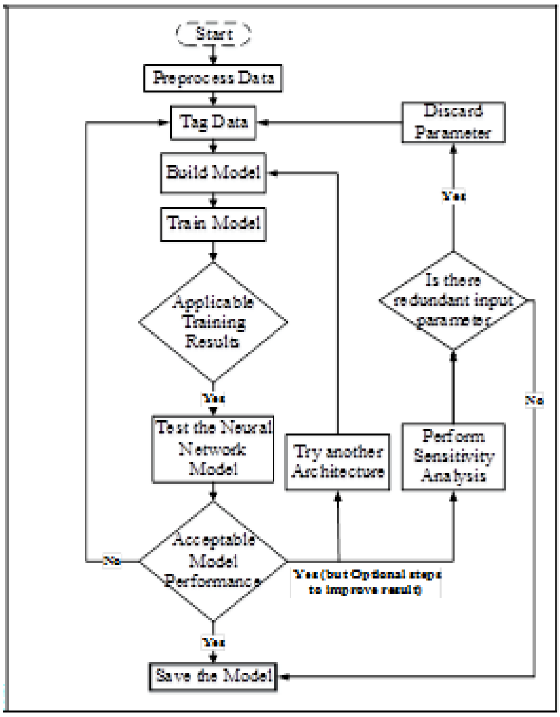

Fig 2: Model development procedure

RESEARCH METHODOLOGY

The research methods applied for this research are correlational descriptive and quantitative research methods. Correlational studies trace relationships among two or more variables in order to gain greater situational insight. Therefore to identify the parameters to be used for developing the cost estimation model correlational descriptive research method was adopted. The quantitative research method was adopted to develop the model that estimates cost.

The study area of this research is Ethiopia excluding the capital city, Addis Ababa. Addis Ababa is the most urbanized, highly congested and populated area fading the resemblance and similarity of the road construction cost among the other areas. Most of the road networks are built up which has a significant influence of right of way issues affecting construction periods and work progress which in turn influences the project cost. The road projects taken as historical feed to develop the parametric cost estimation are from the North, South, East, West and Central region. The central region includes road projects in 250KM radius from Addis Ababa city. The principal tools applied are Microsoft Excel 2013, Neuro Solutions version 7.1.0.0, and Visual Basic Application.

Research procedures

The study started with an intensive literature review and consequently data were collected. The data collection was conducted in two phases as preliminary data collection and final data collection. The preliminary data was collected through 13 experts' interview in open and close ended questions. The experts interviewed include Highway Engineers, Contract Administrators, Quantity Surveyors, University Lecturers and from client side, Project Team Leaders

and Counterparts from ERA. The analysis of the preliminary data collected was carried out for the sole purpose of identifying and determining input parameters. This stage was imperative as not to escape any important parameter that may affect cost of road projects. The next step was the collection of final data to be used as historical basis for parametric estimation. The collected data were compiled from Ethiopian Road Authority Management System (ERAMS), contract documents and reports. A total of 58 data were collected for the model development. The data were then analyzed and put in table format for simplicity and avoidance of double use of specific project.

The succeeding step was development of the neural network model by training the program. Then the model was tested and sensitivity analysis was carried out. A friendly interface was then created to link the neural network model with users. Finally, conclusions were made and recommendations were forwarded in subgroup of the party aimed to be addressed.

MODEL DEVELOPMENT

The cost estimating models are developed in series of steps as shown in Figure 2.

The preprocess of data in this paper is designated to arranging the data in rows and columns, encoding the data, randomizing the data and conveying the total project costs to a common base year. NeuroSolutions creates a new breadboard with typical elements used for neural network configurations chosen and the breadboard is saved. The breadboard created is shown in Figure 3. The chosen models for this research include linear regression, multilayer perceptron and generalized feed forward. NNs are then trained using available data to understand the underlying pattern. During training, both the inputs, representing problem parameters and outputs, representing the solutions are presented to the network normally for thousands of cycles. At the end of each cycle, or iteration, the network evaluates the error between the desired output and actual output.

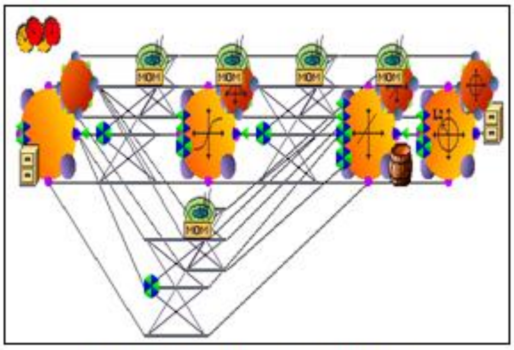

Fig. 3: Snapshot of breadboard created for the conceptual cost estimation model

Then this error is used to modify the connection weights according to the training algorithms used [9]. Back propagation is the type of algorithm adapted, which is a common method of teaching artificial neural networks and uses supervised learning.
The trained network is tested with the data set designated for testing and the network with the best performance is chosen. The performance measures include Mean Square Error (MSE) and Correlation Coefficient (r). Finally a sensitivity analysis was carried out.

ANALYSIS AND DISCUSSION

The analysis and discussion is comprised of three subsections over which preliminary data collected, final data collected and the results of the model developed are analyzed and discussed in detail.

Analysis and Discussion on Preliminary Data Collection

The preliminary data collected was analyzed with the aim of identifying the influential parameters affecting road project cost during conceptual stage. One of the findings of the interview is that two estimate models can be predicted during the early phase of the project, which are conceptual and preliminary estimates. This article only focuses on the conceptual estimation level. The detailed analysis, discussion and results of the preliminary cost estimation model are given on the research paper submitted to Addis Ababa Institute of Technology [19]. The parameters affecting conceptual cost of Ethiopian road projects are briefly discussed.

The parameters identified for the conceptual estimation model are Project location, Project scope or type, Wearing Surface Class, Road length and width, Terrain classification, Project delivery system and Structure intensiveness.

Terrain classification and Structural intensiveness are discarded and taken as a limitation and are recommended for future studies because they could not be compiled for all project data collected. This is because the ERAMS (Ethiopian Road Authority management System) software did not include this parameter as an output report of the system even though the data was initially feed to develop the software.

The two project delivery systems predominantly used in the Ethiopian road construction are design-bid-build (DBB) and design-build (DB). The estimation structures of the two are totally different and therefore project delivery system was not used as a parameter. Therefore, the scope of this study is DBB projects for the reason that only DBB project's data were collected.

Project location required further study on how to classify the location of the study area. The study area of this paper is Ethiopia excluding Addis Ababa. The concerns taken into consideration for classification purpose in this study are climate and sources of four construction materials, which affect construction cost and time. The study was started with an assumption and then the assumption was proven. The assumption was for the location classification to be the same as ERA's regional administrative organization as North, South, East, West and Central region.

The first point of consideration taken to prove the assumption is climate. Rainfall is the major climate measure, as discussed in ERA manual 2013. The rainfall distribution of Ethiopia supports the justification of the assumption as shown with the broken lines on the map below of Figure 4.

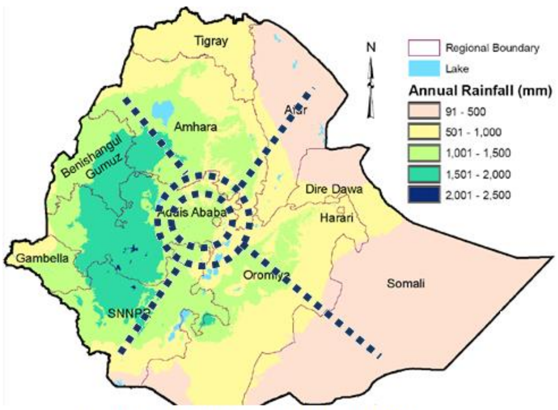

Fig 4: Rainfall distribution of Ethiopia with location categorization [20]

The second accounted point on proving the assumption is the sources of construction materials. The travel distance and cost for transportation of materials depends on the distance between the material manufacturing (importing site) and the construction sites. For instance a road project located in Dire Dawa will have less bitumen transportation cost than a project located in Gambella. This can be easily seen on Figure 5.The materials taken into consideration are asphalt bitumen, cement, fuel and steel reinforcement bars.

Cement is one of the materials used for concrete production mostly for structures in road construction. According to a report of the presentation on the 7th Africa Cement Trade Summit in 2015, the Ethiopian cement industry experiences insignificant import that is only limited to special cements [21]. Therefore the supply of cement for the road construction is from local manufacturers. Dangote, Derba, National, Messebo, and Mugher cement factories are the major suppliers. Figure 5 shows the distribution of the factories is not uniform thought out the country which results in different cement transportation cost along the regions. This similarly supports the assumption of location categorization as north, south, east, west and central region.

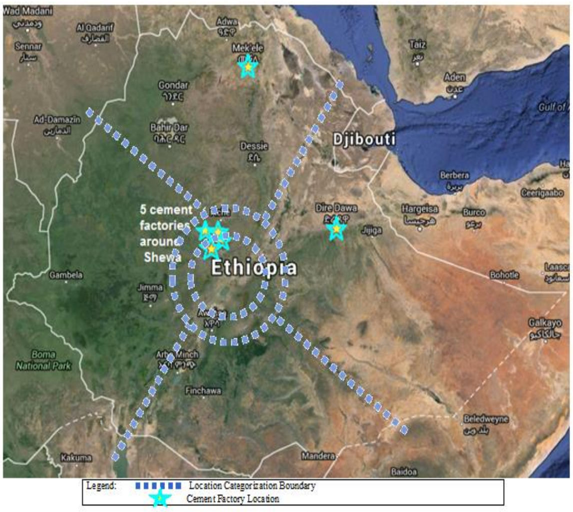

Fig.5: Distribution of Cement factories in Ethiopia in location categorization [22]

From the above discussions, location is determined to be used as influential parameters for conceptual road project cost estimation in the subdivision of south, north, east, west, and central regions. The project scopes that are taken into account by this study are new construction of roads and upgrading of existing roads. Construction duration refers to period of road construction staring from commencement to completion. Construction year in this research refers to the year of construction commencement which is identified as a parameter on this study based on previously executed researches. The year of construction is related to price escalation taking into account the supply and demand balance of the market and inflation rate. The year of construction was used to convey the total project costs to a common base year of 2006 through the application of consumer price index (CPI) from Central Statistical Agency of Federal Democratic Republic of Ethiopia, based on available data as presented on Table 2. The road length and width were identified as an input parameter during literature review and fully supported by the interview. The road length was used to develop the estimation model. But the width was castoff due to the reason that data collected on road width shows that more than 90% of the data is similar. Therefore it was discarded and not used for the model development.

Table 2: Consumer Price index for construction projects.

Year	Consumer Price Index
2006	100.0
2007	112.0
2008	136.6
2009	160.0
2010	195.7
2011	219.4
2012	245.1
2013	267.9
2014	292.3

Analysis and Discussion on Final Data Collected

The final data collection resulted in production of set of data to be used as historical feed for analogous parametric estimation. Totally 58 data were collected and out of these 48 data were used for conceptual estimation model development. The rejected data were not able to be used for model development due to incompleteness of data, inconsistency of data, and because of being on-going project data. The percentage distributions of the data set in terms of location are shown in Figure 6.

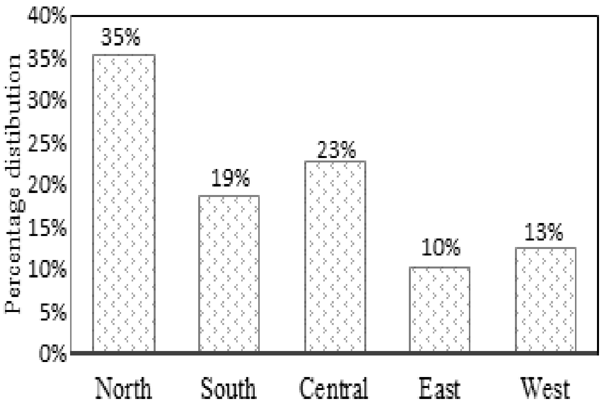

Fig.6: Percentage distribution of location subgroup for conceptual estimation model

Depending on the percentage distribution of data set for location, the north area outshines accounting for the 35% and on the other hand the data set from east region accounts for 10% of the total data set.

Figure 7 shows the percentage of data collected with respect to surface class, which are classified as Asphalt Concrete, Double Bituminous Surface Treatment and Gravel Wearing Course

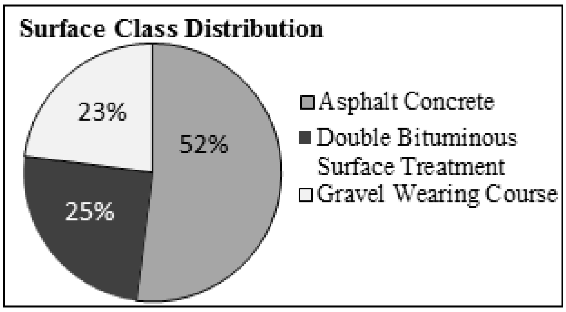

Fig.7: Surface class distribution of data set

The study took the actual completion date and commencement date of the projects to compute the duration, therefore the actual period of construction is taken. The project road length is the other parameter encompassed in the model. The length distribution of the project data collected is shown in Figure 8 after being classified into four.

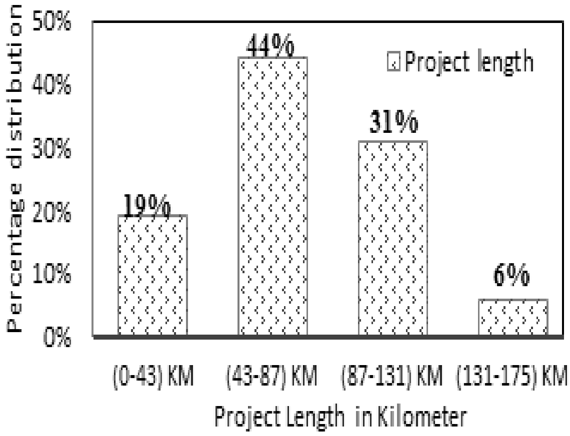

Fig. 8: Percentage distribution of data with length

Discussion on Model development

The percentage of row tags have been varied while training the network to get best accuracy of the models with respect to the performance measures given in testing reports. The data tags of the two models are shown in Tables 3 below.

Training Result discussion

After building a neural network breadboard the next task performed was training the network to develop a model. The training result presented below in Figure 9 shows the best network weight which is saved at the epoch when the cross validation error is minimum for conceptual cost estimation

Table 3: Input/output tags and Percentage of raw tags

Input tags	**Output tag**	**Row tags**	**% of row tags**
Project Location Project Scope Wearing Surface Class Road Length Duration	Total Road Construction Cost	Training Cross Validation Testing	70% 10% 20%

model developed. As it is shown in the figure, the training of network stopped after training and cross validation means square errors (MSE) have reached the minimum and kept constant for continuing trials. The training result of the model shows the MSE approached minimum during the early phase of trials or epoch. After many trials were performed, the neural network configuration or topology with the best performance measure for the conceptual estimation model is Regression General Feed forward network with the architecture of GFFR-1-O-M. The architecture represents a Regression General Network with one hidden layer, Momentum Gradient search and On-line learning updates method. The networks trained were then tested with the provided testing data sets to the performance of the models.

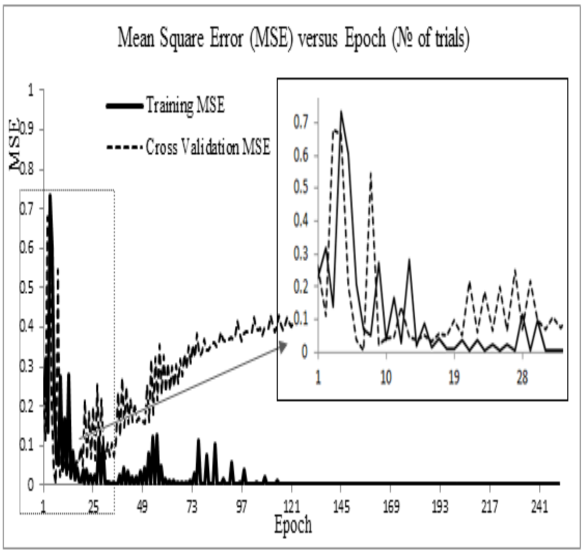

Fig.9: Training report showing MSE values for Conceptual estimation model

Test Results discussion

The model was trained with 48 exemplars and 33 of the exemplars were used for training; 5 of the exemplars were used for cross validation to produce better output for unseen examples; and 10 of the exemplars were used for testing. Figure 10 below shows the desired output and network output of the conceptual cost estimation model developed converge in the same direction in close proximity.

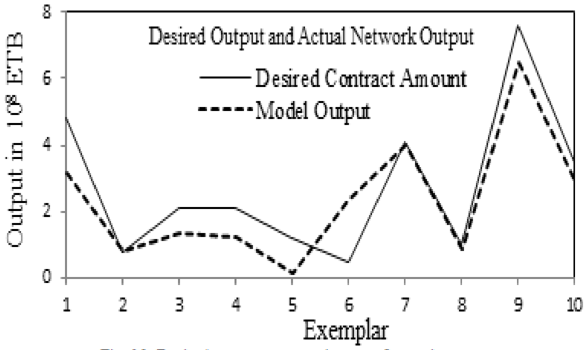

Fig. 10: Desired output to network output for testing exemplars of Conceptual and model

Coefficient of determination denoted as r^2 of network output verses desired graph, which is equal to 0.82, shows that the network put fits the desired output and moves in the same direction, as given on Figure 11. With the provided number of data set, these are promising results towards the possibility of better accuracy with provision of more data points.

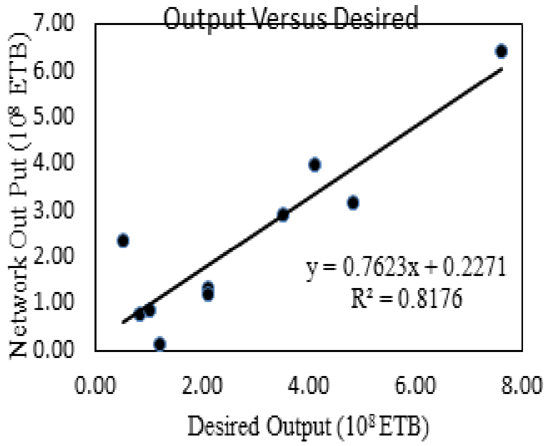

Fig. 11: Scatter plot of desired output Verses network output for testing exemplars

Sensitivity Analysis Result

The sensitivity analysis was carried out for the estimation models that was trained and tested. To carry out the sensitivity analysis the inputs are varied between its mean ±1 of standard deviations while all other inputs are fixed at their respective means. This is done for 50 steps to each side. A report is then generated which summarizes the variation of each output with respect to the variation in each input parameter. The report is presented in Figure 12 below.

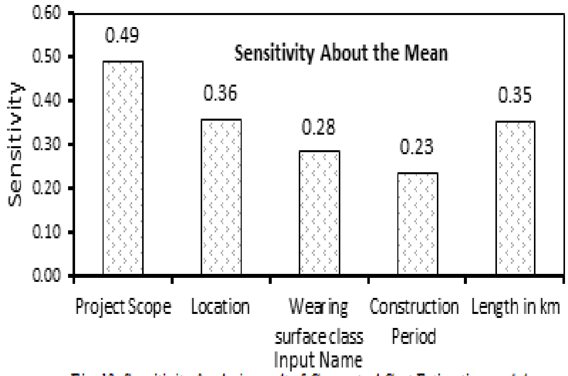

Fig. 12: Sensitivity Analysis result of Conceptual Cost Estimation model

As it is seen on the chart above construction period has the lowest effect on the model; however this parameter was not eliminated or discarded due to the reason that the model was developed for projects completed over different period of years. Project scope and road length have the highest effect of the model. With the number of exemplars provided under consideration, the sensitivity analysis result shows that all the parameters used have indisputable impact on the total construction cost.

Discussion on the Expected Accuracy of the model

The main performance measures this study used to evaluate the performance of the model and to reflect the application of ANN for conceptual cost estimation in Ethiopian road projects are percentage expected and mean absolute percentage errors.

The mean absolute percentage error of the conceptual cost estimation model calculated for the 48 exemplars is 32.58%. This is a very encouraging result with the provided set of exemplars. The model is performed with only 48 exemplars which is not nearly enough to represent road projects in Ethiopia. It is, therefore, predicted to improve with the provision of sufficient data to support all state-of-affairs of each input parameter identified to affect total project cost as a representative sample. The ANN model developed on this research cannot be readily used in the industry but this research is an indication to the prospect of application of ANN for cost estimation of Ethiopian road projects during early phase of the project development.

Structuring User Interface

The friendly user interface is created to use of the model by simply entering the input parameters and receive the predicted total cost is shown in Fig. 13.

Fig. 13: Snapshot of User Interface built

with an example of an upgrading road project cost estimate. The actual contract amount for the construction of the road project is 1,142,567,660.95 ETB. Therefore, the mean absolute percentage error calculated using the actual and desired value is 9% for this numerical example.

CONCLUSIONS

The research was conducted to provide the road construction industry with a computerized and high-tech tool that can estimate cost during the early phase of project development. The conclusions drawn from this research are summarized as follows:

1. Neural Networks have been used in construction engineering and management for prediction and decision-making globally. However advanced technological tools applied worldwide that can expand construction management roles are not fully exhausted and exploited by the Ethiopian road construction industry.
2. Based on the data analysis and discussion the influential parameters for conceptual stage include

construction duration, location, wearing surface class, project scope, terrain classification, structural intensiveness, road length and year of construction.

3. The mean absolute percentage error of the conceptual cost estimation model developed is 32.58%, which has proven that Neural Network is a promising tool for use in the initial stages of Ethiopian road construction projects, providing construction managers access to well-organized and scientifically systemized historical cost data of similar projects on local basis.
4. The application of this cost estimation tool increases accuracy of the cost estimates.

Significantly through the minimization of assumptions cost estimators have to draw due to the existence of low information availability during the initial phase.

RECOMMENDATIONS

The aggregate recommendations drawn are summarized below in a category of the party that is aimed to be addressed.

Decision-Makers in Ethiopian Road Construction Industry

Decision makers of the industry include road authorities, financers and policy makers on road construction in Ethiopia. The applications of advanced project cost estimation tools currently in use by the developed world are relatively at an infant stage in Ethiopian road construction relatively. Therefore it is recommended that authorities embrace and adapt such computerized cost estimation techniques to be applied during early phase of project development. Therefore, the provision of supporting policies along with implementation and enforcement technique establishments that will enable the use of reliable cost estimation tool is recommended.

Baseline for Future Research

The discarded input parameters in this research due to unavailability of data which are project delivery system, structural intensiveness and terrain classification should be further studied.

As mentioned above advanced cost estimation tool can also be applied to Ethiopian building construction projects. For instance the Ethiopian government is currently working towards provision of condominium apartments to the vast urban population. Therefore, future researches can be made in developing cost estimation models for construction of building project.

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