Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 08, August-2019

# Prediction of Construction Materials Cost using Artificial Intelligence Tools

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***Abstract*: Cost estimation is one among the key concerns throughout the project management life cycle and may be thought to be one of the foremost important parameters of a project and also actuation of project success. Fluctuations within the costs of construction materials have great effect on estimating the value of a project and thereby impacting the favorable outcome of the construction projects. The variation in the prices affects project execution costs and eventually impacts the ability to complete the projects. This article focuses on the importance Artificial Neural Networks which is considered as an ideal tool in today's construction market. It benefits the contractor trace past prices and circumstances affecting these prices and then forecast future prices. Artificial intelligence will help to facilitate inexperienced users solve engineering issues, and can also assist experienced users to enhance the work efficiency. In this study, prediction of different construction materials cost using Artificial Intelligence tool is performed, and then validated by comparing it with Linear Trend results on the basis of Co-efficient of Regression ($R^2$).**

***Keywords* — *Neural Networks, Linear Trend Progression, Co-efficient of Regression, Forecast, Linear Regression, Cost Estimation***

## I. INTRODUCTION

A cost assessment at any given stage of project development represents a prediction provided by the value engineer or evaluator as per the available knowledge. Despite its established significance, it's commonly seen a construction project becomes unsuccessful, mainly to attain its goals within available budget. The main cause behind this downfall is changes in construction materials costs. Variations in construction materials cost have considerable impact on the cost of construction projects [1]. Such variations in costs occur irregularly at different rates over time. Therefore, it is important to have a system that is competent of estimating the range of the change in materials rates at reasonable preciseness. There is also need to predict the changes in building materials prices (either increase or decrease) during the execution phase of the project as well as during the preparation of tenders.

Tools that use Artificial intelligence, is one such system which is capable of anticipating construction materials prices. Neural networks are gaining a wide interest in civil engineering issues. They are used as a substitute to statistical and optimization techniques as well as in association with numerical simulation methods [2]. Implementation areas that use ANN in Civil Engineering are e.g. prediction, water control administration and decision helping systems.

*Need of Study*

The unseen price changes influence project execution rates and even affects the ability to finish the projects. As a result of this fast and tremendous change that takes place across the world in construction materials prices, the construction industry is hampered. The rise in building materials costs have become enormous and quick to an extent that a contractor who presents a right offer becomes unable to meet the technical needs and requirements of various construction items. The objective of estimating is to determine approximate construction costs. This is an important aspect that clients take into account when deciding to construct; it determines the practicality of a project, or even offers the idea for budget management throughout tendering and construction. Estimation is used to promote the client to thrust ahead with the scheme design of a project, and to get working drawings drawn up. But, if the estimate is more, it can drive the client away from the chance. Alternatively, if the predicted costs are too low, it may end up in an aborted design, losses, or even castigation from the client.

## II. INTRODUCTION OF ARTIFICIAL NEURAL NETWORK

In the last 10-15 years, a set of different statistical methods, that have recently found very intensive use among construction industry are the artificial neural networks (or ANNs for short).

The construction industries are always trying new efficient methods available to solve issues. There are various techniques attributing a vast variety of different architectures learning schemes and applications. At first we can explain the whole strategy, objectives, effects, advantages and drawbacks; and later we can discuss the basic aspects of various approaches to these methods and how they can be applied in construction industry.

International Journal of Engineering Research & Technology (IJERT)
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Neural networks may be applied to obtain patterns and discover trends that are too complicated to be detected by either humans or different computer techniques, with their extra ordinary ability to derive sense from complicated or unclear data. A well designed neural network can be looked upon of as an "expert" in the kind of information it has been given to examine.

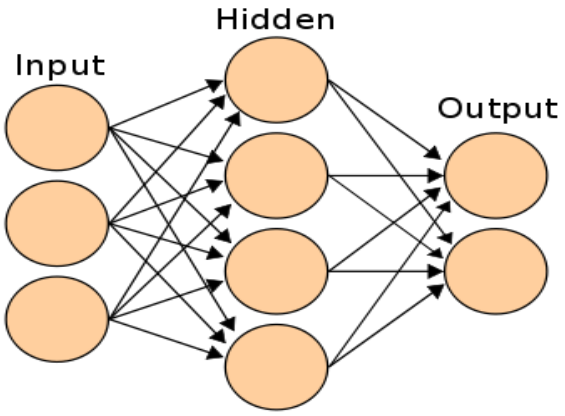


Fig. 1: Neural Network

The most significant thing to keep in mind about all Artificial Neural Networks methods is that they operate best if they are concerning with non-linear dependence between the inputs and outputs. Artificial Neural Networks (ANNs) can be employed to describe or to seek out linear relationship as well, but the ultimate result might often be worse than that if using another easier standard applied math techniques. Owing to the fact that at the start of experiments we frequently don't understand whether or not the responses are associated with the inputs in a exceedingly linear or in a nonlinear means, a decent recommendation is to try undertake or ever some standard applied math technique for decoding the information parallel to the employment of ANNs [3].

## III. METHODOLOGY

A detailed methodology is explained in this section, to predict prices of construction materials for future 5 years and various other benefits that can be extracted from the model. The prediction is done on the basis of data from past 13 years, for 10 most commonly used materials in construction industry.

The methodology comprises of 3 main steps to predict the cost:

- Firstly a detail site survey and case studies to collect quantitative and qualitative data.
- Secondly select a set of proper input to simulate in the neural network based software for obtaining the desire output. Software used is MATLAB.
- Finally analyzing the output and validating it by comparing with linear trend method of forecasting.

*Designing a Neural Network*

Workflow can be explained as follows:

- **Data Preparation**: Data from 2006 to 2018 is collected from various sources for 10 most commonly used materials. It is jotted down in tables for clear understanding.
- **Neural Network Creation**: From various neural network tools, MATLAB is finalized for performing the prediction. Various .m files are created which contain the code for developing the model.
- **Configuration of Inputs and Outputs:** The table is converted to text files which are readable in MATLAB format. These text files (for 13 years data) are then inputted to our code. And, finally the output (5 years prediction) is also converted into text files which are readable and accessible to us.
- **Performance optimization by tuning network's parameters:** Weights/Constants are adjusted as per the pattern of inputs to optimize our performance. 5 Epochs/Iterations are set to obtain best validation performance.
- **Training the network:** Run the main file (Untitled.m) in MATLAB to obtain the results.
- **Validating the result:** The result is compared with results obtain from linear trend method on the basis of co-efficient of regression constant.

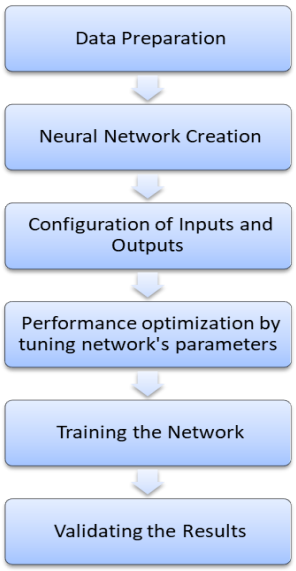


Fig. 2: Workflow of Neural Network Design

International Journal of Engineering Research & Technology (IJERT)
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## IV. DATA COLLECTION

Numerous construction materials are used on construction site. Materials selected in this collection are on the basis of their high frequency of use and necessity.

The data is collected [4],[5],[6] from District Schedule Rates (DSR) of Raigad and Mumbai regions, by actual site visits on various construction sites, retail markets, and online sources, for past 13 years. Below is Data Analysis Table showing Rates of basic construction materials from year 2006 to 2018.

| Year | Price of Materials | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Aggregate (Rs./cum) | Brick (Rs./No) | Cement (Rs./Bag) | Sand (Rs./cum) | Steel (Rs./kg) | Crush Sand (Rs./cum) | Rubble (Rs./cum) | Shuttering Plywood (Rs./Sqm) | Binding Wire (Rs./kg) | Labour (Skilled) (Rs./Head) |
| 2006 | 705 | 2.5 | 245 | 600 | 27 | 600 | 332 | 282 | 35 | 156 |
| 2007 | 811 | 4 | 245 | 650 | 29 | 670 | 385 | 300 | 38 | 151 |
| 2008 | 987 | 3.6 | 245 | 700 | 31 | 710 | 440 | 320 | 42 | 200 |
| 2009 | 882 | 3.6 | 268 | 800 | 34 | 750 | 480 | 350 | 47 | 250 |
| 2010 | 829 | 3.8 | 260 | 900 | 38 | 800 | 519 | 372 | 50 | 325 |
| 2011 | 883 | 4 | 255 | 950 | 29.5 | 850 | 630 | 418 | 76 | 300 |
| 2012 | 918 | 4.5 | 260 | 900 | 44 | 810 | 405 | 530 | 65 | 350 |
| 2013 | 1000 | 5 | 310 | 1009 | 50 | 950 | 475 | 450 | 57 | 436 |
| 2014 | 1175 | 5 | 290 | 1147 | 45 | 1050 | 500 | 485 | 60 | 450 |
| 2015 | 1236 | 6 | 315 | 1236 | 40 | 1130 | 530 | 500 | 64 | 500 |
| 2016 | 1170 | 5 | 330 | 1320 | 41 | 1050 | 610 | 530 | 65 | 600 |
| 2017 | 1080 | 5.5 | 345 | 1410 | 42 | 1000 | 650 | 570 | 66 | 700 |
| 2018 | 1060 | 6 | 350 | 1500 | 43 | 1060 | 706 | 602 | 67 | 800 |

Table 1: Rates of construction materials from year 2006 to 2018

## V.RESULTS AND DISCUSSION

### Output - Neural Network in MATLAB & Linear Trend Progression (in Excel)

In MATLAB (Neural Network), the data for last 13 years of the construction materials is used as inputs, and its corresponding data for next 5 years are obtained as outputs.

Similarly, using Excel the data for last 13 years of the construction materials is used as inputs (Prices are Known_y's and Years from 2006-2018 are Known_x's ), and its corresponding data for next 5 years as outputs ; for respective year i.e. X (required) the new y-value is obtained.

Below table shows predicted values from year 2019 to 2023.

| Materials | Predicted Prices in MATLAB as per Year | | | | | | Predicted Prices in EXCEL as per Year | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2019 | 2020 | 2021 | 2022 | 2023 | | 2019 | 2020 | 2021 | 2022 | 2023 |
| ggregate (Rs./cum) | 1470 | 1470 | 1372 | 1519 | 1617 | | 1213.5 | 1246.9 | 1280.3 | 1313.7 | 1347 |
| rick (Rs./No.) | 6.75 | 7.88 | 7.88 | 8.78 | 7.08 | | 6.2 | 6.5 | 6.71 | 6.96 | 7.2 |
| ement (Rs./Bag) | 386 | 403 | 398 | 403 | 460 | | 352.38 | 361.87 | 371.35 | 380.84 | 390.32 |
| and (Rs./cum) | 1514 | 1514 | 1413 | 1565 | 1665 | | 1530.2 | 1605 | 1679 | 1753.4 | 1827.8 |
| teel (Rs./kg) | 47 | 50 | 54 | 56 | 59 | | 47.71 | 49.10 | 50.50 | 51.89 | 53.28 |
| rush sand (Rs./cum) | 967 | 1011 | 1055 | 1099 | 1143 | | 1168.1 | 1209.3 | 1250.6 | 1291.9 | 1333.1 |
| ubble (Rs./cum) | 769 | 769 | 717 | 794 | 846 | | 674.23 | 697.34 | 720.45 | 743.56 | 766.67 |
| huttering plywood (Rs./Sqm) | 659 | 659 | 615 | 681 | 725 | VS | 624.46 | 650.93 | 677.41 | 703.88 | 730.35 |
| inding wire (Rs./kg) | 70 | 75 | 70 | 79 | 83 | | 74.62 | 77.23 | 79.85 | 82.46 | 85.08 |
| Labour (skilled) (Rs./Head) | 783 | 823 | 923 | 1003 | 1144 | | 760.81 | 812.15 | 863.50 | 914.85 | 966.19 |

Table 2: Outputs obtained from Neural Network (MATLAB) & Linear Trend Progression (Excel)

International Journal of Engineering Research & Technology (IJERT)
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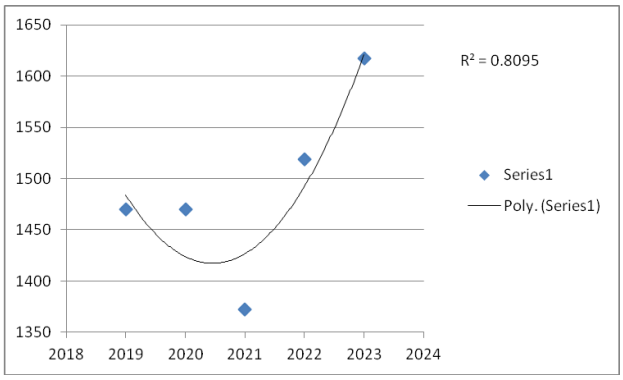
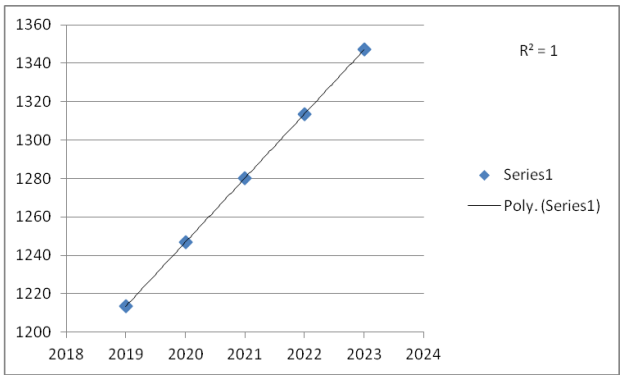
*Comparison and Validation of Results*

Co-efficient of Regression is used to compare the output obtained between Linear Trend and Neural Network method. As the Neural Network output could be Positive or Negative the co-efficient square value is calculated, i.e. $R^2$ (R-square) is obtained for both the methods.

Below graph shows Year vs. Price scattered graph for Aggregate material of MATLAB output displaying value of $R^2$:




Graph 1: Aggregate output using Neural Network




Graph 2: Aggregate output using Linear Trend

Observe that the value of $R^2$ using Linear Trend is 1, and, using Neural Networks (MATLAB) is 0.81.The value 1 indicates that line is a straight one and it's always rising, where as 0.81 indicates that there is variation in data and pattern. This variation could be negative as well.

Moreover, the straight line does not actually do a very good job of capturing the fine detail in the time pattern.

Similarly Value of $R^2$ for other materials is obtained and compared. It varies between 0.7-0.9 using MATLAB. Whereas for Linear Trend it remains 1, since it shows positive progression.

Following table shows Co-efficient of regression values ($R^2$) for different materials by using results from both the Models;

| SR.NO | MATERIALS | Value of $R^2$ using MATLAB | Value of $R^2$ using Excel |
|---|---|---|---|
| 1 | Aggregate | 0.81 | 1 |
| 2 | Brick | 0.74 | 1 |
| 3 | Cement | 0.83 | 1 |
| 4 | Sand | 0.81 | 1 |
| 5 | Steel | 0.99 | 1 |
| 6 | Crush sand | 1 | 1 |
| 7 | Rubble | 0.81 | 1 |
| 8 | Shuttering plywood | 0.81 | 1 |
| 9 | Binding wire | 0.78 | 1 |
| 10 | Labour | 0.99 | 1 |

Table 3: Values of $R^2$ for both the models

## CONCLUSION

In this study, prediction of different construction materials cost using Artificial Intelligence tool is performed successfully, and then validated by comparing it with Linear Trend results.

Following inferences are drawn on the basis of co-efficient of Regression variable ($R^2$) of the results obtained from both the models.

- Neural Network models are suitable for varying data pattern. These are more ideal in real life scenarios in construction industry, as prices may increase and decrease over time.
- Linear Trend Progression models are more data fit models and can be used for uni-directional data. Which means, either data will only increase or decrease, respectively.

Variation in cost of materials can be tracked and analyzed more precisely using Neural Networks. This helps in accurate cost estimation of the project, which is the baseline for any project plan. Therefore, this can be used as a decision making tool in project planning and its success.

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