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Estimation of Contract Duration for Construction on Urban Road Projects within Pokhara Metropolitan City

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Abstract
Implementation status of projects is poor in Nepal, and fails to obtain expected results, hence schedule and price overruns are common. Construction project operates in a dynamic environment, with a great deal of complexity, uncertainty, competition for resources, flexibility and rapidly changing construction technologies. Urban road construction projects include internal, task and external environment which provides resources and limitations. So, appropriate method is required for the proper estimation of contract duration. This study aims in establishing an empirical relation for estimation of contract duration. A total of 28 urban road projects of similar nature with estimated amount ten million within Pokhara Metropolitan City (PMC) at immediate past three fiscal year from 077/78 were taken into consideration. The data was then projected to Browmillow's time – cost model. Based on the primary data collected through desk study from the sampled urban road projects within PMC, regression analysis was carried out to develop an empirical relation between time and cost of the project as:

$$T = 48.202C^{0.3759}$$

This relation is applicable for the urban road projects within Pokhara Metropolitan City with estimated amount greater than ten million for the public entity, contractors and consultants involved in construction as well as in procurement works.

Keywords
Browmillow's Time–Cost Model, Extension of Time, Project Environment, Regression Analysis

1. Introduction

Road construction project involves extensive works with varied activities and uncertainties. The nature of the work, construction technologies, socio-economic and political environment are the reasons for uncertainties. With the consideration of these unseen and unpredictable uncertainties proper estimation of contract duration for construction of urban road project is of big deal. Time overrun is a project's failure to finish on time as a result of critical path activities being delayed, which causes the project to run over its intended schedule. One measure for assessing a project's effectiveness and the project office's competence is construction time. One of the main objectives of the client and contractor is the timely completion of the construction project because if completion is delayed, each party tends to suffer more expenses and lose potential income[1].

In Pokhara Metropolitan City, the public tendering of urban road projects is by Public Procurement Act (PPA) – 2063 and Public Procurement Regulation (PPR) – 2064 along with its latest amendment as well as the directed guidelines prepared by Public Procurement Monitoring Office (PPMO). In the regulation, the rule no. 9, and on Special Condition of Contract (SCC) of Standard Bid Document, there is the provision of the contract duration; however, these provisions lack to define the way of estimating the contract project duration [2]. The PPR has been amended twelve times till date and each of the amendment includes the change in the provision of extension of time (EoT). So, it seems that the government itself is in the phase of trial-and-error experiment in the regards of contract duration and EoT. Hence to implement the provision of liquidated damage and bonuses in the contract document in a transparent manner, it is essential for the appropriate estimation of contract duration. If the construction duration is over estimated, it will lead to the overhead changes; and if it is under - estimated, it will lead to the unwanted documentation work for schedule variation and also can be the reason of conflict between owner and contactor. Thus, a practical approach must be applied rather than a theoretical method for the proper estimation of contract duration.

1.1 Research Objectives

This research paper aims to develop empirical formula for the prediction of project duration by establishing time and cost operational relation for urban road projects within Pokhara Metropolitan City.

2. Literature Review

2.1 Present Practice of Constructional Project Scheduling in Nepal

Till now, there hasn't been a standardized approach or instrument utilized for contract scheduling; instead, it's been done haphazardly, without consideration for factors like the work's type, the location, or the number of workable days. Similarly, due to each project's unique nature, there is no consistency in the duration of the contracts. Also, there is no any specific methods such as bar chart, CPM, PERT referred by the public entity for the scheduling purpose. Based on the past practice and working experience of the particular officials involved in the procurement unit, the contract duration is fixed. Similarly, there is no precise process or approach recommended in the PPA, PPR, and Standard Bid Documents created by the PPMO for time estimation. The Department of Roads (DoR) had published a methodology and a formula for determining the project's duration, but it had not been revised in seven years, and it has been advised that the DoR guideline be used only as a general reference and not for precise time estimation[3].

2.2 Browmillow's Time Cost (BTC) Model

Time cost model is the concept defined for the appropriate estimation of constructional contract duration. Bromilow in 1969, engineer from Australia, has carried out research for building projects so as to interconnect the project time with the cost and is still considered to be the pioneer in this area[4]. Based on the collected data from 883 sampled building construction projects of Australia in 1969, Browmilow has formulated an empirical relation and developed the model termed as Bromilow's Time Cost (BTC) model. The model was created with the aim of accurately estimating the construction duration using project estimated costs, where the project duration was highly dependent on the project cost. The model was designed using linear regression analysis.

Browmillow's time cost model gives the empirical formula as:

$$T = K * C^B$$

Where, T = Constructional Project Duration,

C = Actual project costs, including changes and variations,

K = Constant presenting the level of performance over time for unit cost,

B = Constant expressing the relationship between project size as evaluated by cost and time performance.

2.3 Worldwide Practice of Time Cost Model

Some of the highlighted works for contract project duration estimation based on Browmillow's Time Cost model are described as: Jarkas et al., in 2016 had carried out the study on prediction of contract duration for building construction based on BTC model[5]. In order to estimate the contract duration for building construction in Kuwait and to offer a substitute model that takes other potentially significant project scope elements into account, the study's goal was to examine the applicability and validity of the time cost model. For this, information was gathered from 113 residential buildings and 74 official buildings that were finished between the years of 2004 and 2010. In order to create a time-cost model and a multiple regression model, the primary data had to be evaluated. The researcher also took into account the size of the project's building site and the number of floors above and below ground. The research established the empirical formula for the prediction of construction duration for residential building as:

$$T = 28.79C^{0.192}$$

with 80.3% accuracy of the model predictability for constructional project duration and for official buildings as:

$$T = 792C^{0.277}$$

with 84.9% accuracy of the model predictability for construction project duration.

The study on the correlation between the cost and time of construction projects was conducted by Kaka and Price in 1991[6]. To model and develop relationship, the author has collected two sectoral sample as 661 building projects with cost above 695 million euro which includes all types of commercial, industrial, residential and public projects, and 140 road contract projects with cost above 120 million Euro. The research gave out the empirical formula for the prediction of construction for building project as:

$$T = 291C^{0.205}$$

and, for the road project as:

$$T = 301.4C^{0.215}$$

Kumaraswamy and Chain in 1995 in Hongkong used BTC model for the estimation of construction project duration for public buildings, private buildings and civil works[7]. Based on the regression analysis of historical data, the BTC model was found to be

$$T = 188.7C^{0.259}$$

,

$$T = 206.5C^{0.2}$$

and

$$T = 250.5C^{0.206}$$

respectively for public buildings, private buildings and civil works.

Hoffman et al., in 2007 carried out the research on estimating performance time for construction projects in USA applying both BTC model and multiple regression model to project's data of 856 faculty projects completed between 1988 and 2004[8]. From the research, the empirical formula for the prediction of contract duration for faculty projects within USA as:

$$T = 26.8C^{0.202}$$

with 33.7% accuracy of the model predictability.

Sun and Xu in 2011 carried out the research on estimation of time for Wenchuan earthquake reconstruction in China[9]. For this, the BTC model and the Elm a Network (EN) model have both been designed to forecast the length of time that reconstruction projects following the Wenchuan earthquake will take to complete. Data from 72 completed construction projects in six cities that were severely impacted by the big Wenchuan earthquake were gathered for the study. The EN model provides more accurate time predictions for the reconstruction than the BTC model, despite the fact that the BTC model was more practical for implementation in practice, according to a comparison of the results from the two models for the accuracy of construction duration forecast. The research revealed that the empirical formula for the prediction of contract duration for earthquake reconstruction projects within Wenchuan, China as:

$$T = 42.4C^{0.286}$$

with 52.2% accuracy of the model predictability.

Research on the application of Bromilow's time-cost model to construction projects in Ghana was conducted by Ameyaw et al. in 2012[10]. For this the historical data of 13 office building projects, 27 residential building projects and 22 classroom building projects with altogether of 62 building projects completed within the period of 2000 to 2007 were made fit for the multiple regression analysis using SPSS. This research suggested that the empirical formula for the prediction of contract duration in Ghana for classroom building projects as:

$$T = 512.28C^{0.463}$$

with 46.3% accuracy of the model predictability, office building projects as

$$T = 344.59C^{0.684}$$

with 68.4% accuracy of the model predictability, residential building projects as

$$T = 2.807^{0.399}$$

with 39.9% accuracy of the model predictability and in a combined way,

$$T = 3.170C^{0.378}$$

with accuracy of the model predictability as 37.8%.

2.4 Time cost Model in Nepal

Different research works had been carried out for the estimation of construction project schedule in Nepal based on time cost models. Mishra et al., in 2020 carried out the research on "Assessment of time – cost model of public health buildings in Nepal" where 35 public health buildings constructed under DUDBC were taken as sample[11]. The data were analyzed, and an empirical formula for the construction project schedule based on time cost model was developed as:

$$T = 487.5 * \frac{C}{79.96}^{0.293}$$

Where, T = Construction Time in days,

C = Cost of Construction in Millions, NRs

Pokharel et al., in 2020 carried out the research on "Estimation of construction duration for roads and bridges in Nepal" where 83 number of bridges and 78 roads constructed under DoR were taken as sample for study purpose[3]. The data were analyzed, and an empirical formula for the construction project schedule based on time cost model was developed as:

For Bridge:

$$T = \frac{I}{I_0 * 0.64} * C_1 * C_2 * 111.018 * C^{0.2150}$$

For Road:

$$T = \frac{I}{I_0 * 0.64} * C_1 * C_2 * 92.482 * C^{0.2159}$$

Where, T = Duration in days,

I = Present NRB index,

I_0 = NRB index value of fiscal year 2019/20 (Feb),

C_1 = Coeff of vehicle accessibility ,

C_2 = Coefficient for complexity of work,

C = Cost of construction works in lakhs, NRs.

Joshi et al.,in 2021 carried out the research on "Operation of time and cost estimation of road and bridge projects" where 83 bridges and 78 roads constructed under DoR were taken as sample[12]. The data were analyzed, and an empirical formula for the construction project schedule based on time cost model was developed as:

For Bridges:

$$T = 111.018 * C^{0.215}$$

For Roads:

$$T = 92.482 * C^{0.2159}$$

Where, T = Time in days,

C = Cost of construction on Lakhs.

Table 1: Research Matrix

Objective	Sources of Data Collection	Analysis
To develop the empirical formula of project duration by establishing the time and cost operational relation.	Literature Review, Desk Study, Documentation Review, Analogy Techniques	Quantitative and Analytical approach

3. Research Methodology

3.1 Research Design

The research was carried out on the urban road projects implemented by Pokhara Metropolitan City, Office of Municipal Executive. The research is based on quantitative and analytical approach based on adoptive research of Browmillow's Time Cost (BTC) model with non-probability sampling method. The research matrix of the study is shown on table 1.

3.2 Data Collection

The research is based on the construction of urban road projects of similar nature under PMC with estimated amount greater than ten million rupees in fiscal year 075/76, 076/77 and 077/78. The population of urban road within PMC for data collection was taken 28. According to statistics, a minimum of 10 samples must be taken for each variable in order to do regression analysis so, census-based sampling method was used for the research where all of the urban road projects were taken as sample for the study.

3.2.1 Primary Source of Data

The primary data such as estimated cost, contract amount and completion cost of project, initial contract duration and exact contract duration of the sampled urban road projects within PMC were collected from desk study, contract documents through review and analogy techniques.

3.2.2 Secondary Source of Data

Related books, journals, papers, articles, websites, thesis reports, booklet were used for the collection of secondary data.

3.3 Data Analysis

The value of a variable was predicted using regression analysis based on the value of another variable. In order to put the data into a linear equation, regression analysis was performed. Equation development was undertaken using MS-Excel and regression analysis.

Table 2: Statistical Parameter for Regression Analysis

Regression Parameters	Value
n	28
$\sum Y$	165.32
$\sum X$	151.14
$\sum XY$	903.95
$\sum X^2$	984.68
$\sum Y^2$	846.6

As per Browmillow's time cost model, the contract duration is given by,

$$T = K * C^B$$

Taking Logarithmic on both sides

$$\log T = \log K + B \log C$$

Where, T = Contract Duration,

B, K = Constant,

C = Cost of Contract.

Also, the standard linear equation is,

$$Y = A + BX$$

Comparing corresponding terms,

$$Y = \log T$$

$$A = \log K$$

$$X = \log C$$

The statistical parameter for the regression analysis was calculated and is shown on table 2. Regression analysis was used to fit these statistical variables into the linear equation. So, after the regression analysis, the slope and intercept of time - cost line give the value of constants K and B. Here, the higher value of R2 shows the better the predictability of the model.

4. Results and Discussions

The graph of log-log regression analysis using MS-excel is shown on figure 1.

Table 3: Parameters of log-log Regression Analysis

Intercept Value	Slope Value	Statistics R^2
3.8754	0.3759	0.5093

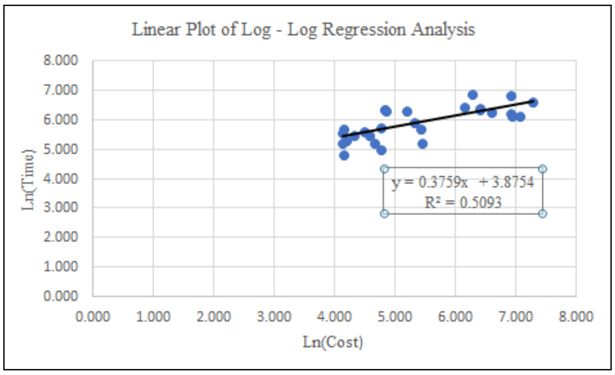

Figure 1: Linear Plot of Log - Log Regression Analysis.

The parameters of log-log regression analysis of urban road data are summarized on table 3.

The empirical relationship incorporates 50.93% of the variability in the road data, according to the road project's coefficient of determination R^2, which is 0.5093. R^2 does not have a specific limiting value, however values between 0.4 and 0.6 are considered acceptable. Therefore, the more R^2 values there are, the more predictable the model is. Additionally, it was discovered that the slope and intercept values were 0.3759 and 3.8754, respectively, from which it is possible to calculate the values of the constants K and B. The empirical formula demonstrates for project costs above ten million dollars that the value of K implies the number of days needed to complete a road project of unit cost. The regression analysis's slope value, which represents the size of the project based on its cost and the length of the contract, is found to be 0.3759. Here, a higher slope value indicated a greater impact of project size on duration. Comparing the slope and intercept parameter of regression analysis with the linear equation of BTC model in terms of log as:

$$Intercept = \ln K = 3.8754$$

Taking exponential on both sides, the value of K as 48.202 is obtained. Similarly. The slope gives the value of B as 0.3759.

The output of the linear regression analysis of the data of urban road projects within PMC in the form of Browmillow's time cost model is defined on equation

Table 4: Summary of Model Predictive Errors for Urban Road

Maximum Error (%)	Minimum Error (%)	Average Error (%)
50.58%	-94.54%	-7.76%

as:

$$T = 48.202C^{0.3759}$$

So, the equation hence obtained in the form of time - cost relation was used to find the duration required for the projects. Based on this, empirical formula was derived. The comparison was made between the actual time required for the project and the estimated time obtained from the empirical formula from BTC model and the deviation between the actual and predicted duration is shown on table 4.

5. Conclusion and Recommendation

Based on the time cost model, following equation is obtained as an empirical relation for predicting contract duration for construction of urban road projects within PMC.

$$T = 48.202C^{0.3759}$$

The Browmillow time – cost model has become an effective tool to predict the contract duration during the procurement phase. This model is helpful to estimate the project duration.Since the model is based on the historical data of the urban road project, the predictability of the model is valid if the nature of the work is similar.

Since the research is based on the urban road projects within PMC with estimated amount above ten million, further study can be conducted by taking other projects like buildings, bridges, parks, footpaths, river training works, etc. within PMC. Also, modification of the model can be made taking the consideration of other factors like nature of work, geography of an area, availability of construction material, etc. which have the vital role on determination of contract project duration.

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