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ENHANCING PROJECT DELIVERY IN GAINDAKOT MUNICIPALITY, NEPAL, THROUGH THE BROMILOW TIME-COST MODEL: A STRATEGIC MITIGATION APPROACH

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Abstract. Construction projects rely on the precise interplay of time and cost to achieve success. This study explores this critical relationship, exploring how contract size influences these vital metrics and proposes data-driven mitigation strategies to ensure projects resonate with optimal performance. This study employs Bromilow's time-cost model to investigate the relationship between project duration and expenditure. A statistically significant positive correlation was found, with a linear regression model showing a strong association (R^2 = 0.836) between the two variables. The analysis also reveals a more detailed role for contract size, suggesting a potentially limited influence on time and cost variations. Several factors can disrupt the harmony of project execution, thereby impeding its performance concerning both cost and time. Key factors contributing to this disruption include the unreliability of contractors, inadequacies in site management, breakdowns in communication channels, delays in decision-making processes, and constraints within budgetary allocations. The identification and subsequent mitigation of these diverse challenges emerge as pivotal tasks in ensuring the smooth arrangement of project endeavours. Bromilow's model provides a path to a more harmonious performance. It unveils a logarithmic correlation between project cost and duration, indicating a constant value of 24.35 days for projects exceeding one million Nepalese rupees (NPR). This underscores the substantial influence of project scale on time, emphasizing the necessity for management approaches based on project size. To achieve a truly masterful performance, the study advocates for a holistic management approach. This includes proactive decision-making, establishing clear and effective communication channels that resonate with all stakeholders, and maintaining meticulous financial oversight to ensure accurate budgeting and efficient resource allocation. By implementing these strategies, project teams can navigate the complexities of construction with greater ease, optimizing both time and cost performance. Ultimately, they can turn projects into symphonies of success, ensuring their completion on time, within budget, and to the highest quality.

Keywords: *Bromilow's time-cost model, performance optimization, management approach, proactive decision making.*

INTRODUCTION

The construction industry plays a crucial role in the development of infrastructure, contributing significantly to the economic growth of regions and nations. Gaindakot Municipality, much like other urban areas, has experienced a notable increase in construction projects aimed at enhancing its infrastructure to meet the growing needs of its population. However, despite careful planning and execution, completed construction projects often deviate from the initially estimated time and costs, giving rise to concerns among project managers, investors, and policymakers (Koirala, 2021).

From project initiation to completion, various factors such as unforeseen delays, resource constraints, and evolving regulatory landscapes may impact the intended project timeline and budget. By conducting a thorough investigation into completed projects in Gaindakot Municipality, this study seeks to contribute valuable insights to the broader discourse on construction project management (Sigdel et al., 2022). Also, in the related study by Sigdel (2023), it was found that better management of materials and equipment can reduce the delays in building construction to some extent. By gaining a better understanding of how time and cost dynamics influence construction projects, the research seeks to contribute to the ongoing improvement and advancement of construction practices and project management methodologies.

Current general practice in the construction industry shows that it is rare for the majority of projects to be completed within the scheduled time, budgeted cost, and expected quality. The main reason behind this is that the construction project is unique in nature, time-consuming, high-cost, and fraught with uncertainty. As a result, claims and disputes have become common, especially in large-scale civil engineering contracts. However, it has become very difficult to complete the project within the time and cost specified in the initial contract document. Time and cost overruns are common phenomena in almost all projects. During the construction stage, there are many unexpected problems and changes to the original design, causing cost and time overruns (Taye, 2016).

The construction industry is an important part of the economy and significantly impacts the efficiency and performance of other industries. Without the construction of infrastructure, it is impossible to make a large-scale investment in manufacturing, agriculture or service industries. One of the main goals and principles of any public or private department involved in the implementation of the project is to improve project performance by minimizing costs, completing the project within the allocated budget and time frame, and improving quality (Rahman et al., 2012). Projects fail to meet goals for many reasons: poor time and budget performance, failure to deal with complexity, etc.

Local governments in Nepal emphasize their autonomy and their potential to improve citizens' living standards by utilizing local resources for various development purposes (Pandeya, 2015). The fiscal transfer system from federal and provincial governments to local governments decentralizes resources and empowers local authorities (Chaudhary, 2019). This system involves allocating financial resources through grants, subsidies, and revenue-sharing mechanisms, enabling local governments to address specific community needs. So, we can underscore that effective project management is crucial for successful construction projects, ensuring they stay within budget and timeframe, as taxpayer money flows from higher levels of government to local goals for development.

This study focuses on evaluating the performance of completed construction projects within the Gaindakot Municipality, specifically assessing the cost and time efficiency of these projects. Project cost overruns and schedule delay are major and widespread problems in the construction industry (Berihu et al., 2023). Project construction experience obstacles and constraints in implementation are very undesirable conditions because they would be very detrimental to all parties. Every construction project has a specific implementation plan, including when the implementation of the project should begin, when it should be completed, how it will be carried out, and how the resources will be provided (Rauzana, 2016). By analyzing historical project data and comparing it with initial estimates, this study aims to provide insights into the factors influencing project success and identify areas for improvement in future projects.

1. CAUSES OF COST AND TIME OVERRUNS

It is seen that the causes of time and cost overruns differ from location to location. Less emphasis on planning, poor contract management and poor pre-planning process have been ranked in the first, second and third positions as the causes of time and cost overruns as per a study conducted by Taye (2016).

Some researches highlighted that design change was found to be the key factor having the most significant effect on the schedule/cost performance of the engineering and construction phases. The scheduled performance of the procurement phase was found to be highly affected by a shortage of resources. This factor, along with price fluctuations and poor economic conditions, can increase the cost of supervision, clients' financial issues and severe weather conditions, which mainly influence the engineering and construction phases and procurement phase. Other schedule/cost performance factors are the owners' untimely decision-making, poor communication between stakeholders, and poor site management (Yadav & Mishra, 2019). A study by Rahman et. al. (2012) portrayed that the major factors affecting time and cost performance are design and documentation issues, financial resource management, project management and contract administration, contractors' site management, information and communication technology, material and machinery resource, labour (human) resource and other external factors. Terrain conditions, weather conditions, variation of order, and availability of labour are major causes for delays in construction projects.

Unusual low bid, inadequate planning, pre execution preparation regarding land acquisition, utility relocation, approval delay in receiving clearance from various authorities, poor site management and supervision by contractor due to large number of work in hand and tendency of change of project manager of various project offices (Suwal & Shrestha, 2016).

Lack of materials in markets, strikes, external or internal military action and border closures, shortage of construction materials at site, delay of material delivery to site, cash flow problem during construction, poor site management, no adherence to materials standards relating to site storage, poor economic conditions (currency, inflation rate, etc.), major disputes and negotiations and suspension of work by owner or contractor are considered to be major delay factors.

The easy reasons to prove justification for delay and cost overruns are climate change, inflation and natural calamities, budget allocation, overambitious contract durations, faulty premises at the time of designing and starting the projects, weak monitoring and supervision system, lengthy litigation process to grant project approval, favouritism to the contractors based on the political and financial interests, power influence on the project rather than needs and cost benefits analysis, frequent changes in government and politically favoured government officials, who work to please power rather than interest of the country and society (Arain et al., 2004). Similarly, studies have indicated some reasons, such as the interest of the client group to earn money and take personal benefits, lack of awareness of common people towards what is being constructed in their areas.

Legal Provisions Prevalent in Nepal

Public Procurement Regulations 2007 (Rule 118) and amendments thereof have provided some basic guidelines for the preparation of variation orders for the projects administered by public entities. There are basically two types of variation orders taken into consideration, the first being unchanging of the contractual drawings, specification and design, which are not dealt with so seriously; however, if there is a change in the above-mentioned parameters, the evaluation and assessment of variation orders are stringent. Nevertheless, the variation orders in development projects in Nepal are taken very seriously, and some of the projects are not moving smoothly due to the unavailability of timely decisions on such variation orders.

During the construction, especially in a re-measurement type contract, not all the items listed in the Bill of Quantities are appropriate to be used. Instead, some of the new construction items need to be introduced, which may lead to another type of variation order (Sambasivan & Soon, 2007). However, the same rule has barred the project management from providing new rates other than those stipulated in the original contract.

Approval of Extension of Time (EOT). If the reasons stated in the application are proven to be true after a thorough examination, the EOT can be approved as per Public Procurement Monitoring Office rules:

- the officer who approved the procurement can approve an EOT of up to 15 % of the initial project length,
- the departmental chief can approve EOTs that are greater than 15 % and up to 25 % of the initial project duration,
- the secretariat of the concerned ministry/entity can approve EOTs of more than 25 % but less than 50 % of the initial project duration,
- there can be no EOT that exceeds 50 % of the initial project duration. The contract should be cancelled due to such requirements (Aryal & Dhakal, 2022).

2. BROMILOW'S TIME-COST MODEL

The Bromilow time-cost model is a valuable tool in the field of construction project management, designed to enhance the understanding of the intricate relationship between time and cost factors (Chan, 2001). Developed by Dr James Bromilow, this model has gained recognition for its applicability in assessing and predicting the dynamics of construction project performance. The literature review below provides an overview of the key aspects and contributions of Bromilow's time-cost model:

$$T = K \times C^{B} \text{ (Bromilow, 1969)},$$

where T is the duration of the construction period, K is a constant for time performance, C is the final cost of building, and B is a constant of time performance in cost. The values of K and B are determined based on historical data and experience.

These constants are specific to a particular organization, type of project, or development environment. The variation in K and B can occur for several reasons, such as project complexity, technology and tools, team experience, development process, and organization-specific factors (Mak et al., 2000).

This research aims to investigate the details of Bromilow's time-cost model, examining its theoretical foundations, practical applications, and potential implications across various industries. By exploring the strengths, limitations, and real-world effectiveness of this model, this study attempts to contribute to the advancement of project management theory and practice, ultimately empowering organizations to achieve greater efficiency and success in their project (Guo et al., 2019).

3. METHODOLOGY

This study focuses on building projects within the Gaindakot Municipality, constructed through self-financing and grants from the Government of Nepal and the Provincial Government. From the annual procurement plans (APP) of the past five fiscal years, 11 completed, mixed-financed building projects were selected for analysis.

The selection is based on the following key considerations:

- Mixed financing: Projects funded through grants and internal resources, reflecting real-world financial structures.
- Representative diversity: A range of building types and sizes, ensuring broader applicability.
- Data availability: Selection of projects with complete and accessible data from municipal records.
- Research relevance: Projects aligned with the objective of analyzing time and cost performance.
- Practical feasibility: Completed projects with reliable data enabled robust analysis and practical recommendations.

Thus, the selected projects provide a relevant and comprehensive basis for understanding construction performance within the Gaindakot Municipality.

Table 1. The List of Projects Under Study

#	Project Name	Contract ID	Allocated budget (NPR)	Intended start date of works	ECT
1	Construction of municipal building (Phase II)	02/GM//NCB/074-075	18 500 000.00	28-11-2017	12 Months (220)
2	Ward office building construction-11	GM/NCB/02/75/76	9620 326.00	28-03-2019	11 Months
3	Dondeni multipurpose building, construction ward No. 3	GM/NCB/01/076/077	12 779 732.79	13-03-2020	5 months (78)
4	Construction of municipal building (Phase III)	06/GM/NCB/2076-77	8707 238.75	30-06-2020	12 months (84)
5	Covered hall, building construction ward No. 3, 4, and 8	04/GM/NCB/076--077	8070 767.00	25-03-2020	3 months (78)
6	Construction of Shree Dipjyoti Adharbhut Bidhyalaye, Gaindakot Municipality-14	01/GM/NCB/077/078	13 471 806.40	23-11-2020	6 Months (84)
7	Construction of Meeting Hall in Gaindakot Municipality	02/GM/NCB/077-78	18 059 877.00	27-11-2020	7 Months (197)
8	Construction of ward office building at ward No. 4, Gaindakot Municipality, Nawalpur	03/GM/NCB/2079-080	14 806 808.00	15-11-2022	12 Months (193)
9	Construction of RCC store building, mosaic parking tile laying, bio-engineering and landscaping work in Gaindakot Municipality	05/GM/NCB/2079-080	15 395 229.30	28-02-2023	5 months (83)
10	Construction of Meeting Hall at Gaindakot Municipality (Phase II)	08/GM/NCB/2078-079	13 254 401.00	28-02-2022	5 months (192)
11	Construction of Covered Hall at Regional Stadium in the Gaindakot Municipality ward No. 3, 4 and 8 (Phase II)	05/GM/NCB/2078-079	16 001 758.00	07-01-2022	6 months (184)

The framework of study based on Bromilow's time-cost model establishes a mathematical relationship between project duration and cost, expressed as Equation (1) (Bromilow, 1969):

$$T = K \times C^{B}, \tag{1}$$

where
T – project duration;
C – actual cost of the project, including fluctuations and variations;
K – a constant showing the level of time performance for unit cost;
B – a constant describing how the time performance was affected by project size as measured by the cost.

Taking the logarithm on both sides,

$$\mathrm{Ln}\,(T) = \mathrm{Ln}\,(K) + B \times \mathrm{Ln}(C). \tag{2}$$

Also, the equations of linearity are,

$$Y = A + BX. \tag{3}$$

Comparing corresponding quantities,

$$Y = \text{Ln}\,(T). \tag{4}$$

Similarly,

$$A = \text{Ln}\,(K). \tag{5}$$

Also,

$$X = \text{Ln}\,(C). \tag{6}$$

This approach will provide decision-makers in Gaindakot Municipality with a reliable framework for estimating construction costs and time. The results will be compared with similar studies for validation.

4. RESULTS AND FINDINGS

The statistical parameters obtained from the regression analysis stated in Excel were used to determine the value of constants and to fit into Bromilow's time-cost model. The statistical parameters obtained from the data were made to fit the linear equation using regression analysis. The result of the log-log regression for building data is summarized in Table 2. The coefficient of determination adjusted (R^2), for the building project is 0.669. This implies that 66.9 % of the variability in the building data is incorporated by the respective empirical relations. There is no particular limiting value of R^2 based on which the model can be judged. A higher value of R^2 indicates better predictability of the model. However, the value of R^2 in the range of 0.4 to 0.6 is acceptable in simple as well as multiple linear regression.

Table 2. Summary of the Log-Log Regression of Building Project Data

Sector	Intercept		Slope		Statistics
	Value	Std. error	Value	Std. error	Adj. R^2
Building	3.1928	0.47	0.9758	0.211	0.669

The intercept value of 3.1928 is obtained from log-log regression analysis in selected building projects. After solving, we get

$$T = 24.3583 \times C^{0.9758}. \tag{7}$$

This gives the value of constant K in Equation (5), which is 24.35 for the building project. This value of K implies the number of days required for completion of a project unit cost (one million). 24.35 days are required for the completion of a building project worth a contract amount of NPR 1 million. However, this statement cannot be generalized as the model is made to suit only amounts greater than 5 million. The slope intercept value of 0.9758 in building projects indicates the influence of the size of the project (measured by its cost) on the contract duration. The larger the value of slope intercept, the larger is the influence of project size on the duration. The linear plot of log-log regression depicting Ln (cost) vs Ln (time) is shown in Fig. 1. A larger value of slope intercept indicates greater influence of cost on the duration.

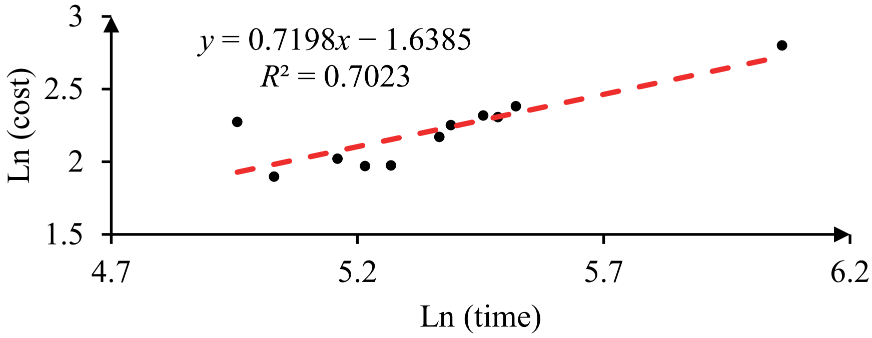

Fig. 1. Linear plot for log-log regression for the building projects.

4.1. Predictability of this Model

After getting the K and B values for Bromilow's time-cost model, time estimate (contract duration) from the obtained equation, intended contract duration, and actual project duration in the Gaindakot Municipality were compared, and the person's coefficient of correlation was calculated. To test the predictability of this model, the coefficient of determination for intended, actual and predicted duration with respect to cost is assessed. The result is shown in Table 3.

Table 3. Predictability of the Model

Particular	**Intended duration**	**Actual duration**	**Predicted duration**
Coefficient of determination (adjusted R^2)	0.0978	0.75661	0.999973

The coefficient of determination (adjusted R^2) provides insights into the effectiveness of a predictive model in explaining the variability in the dependent variable. In Table 3, the values of 0.0978, 0.75661, and 0.999973 reflect varying degrees of explanatory power. A coefficient of determination of 0.0978 suggests that only about 9.78 % of the observed variability in actual duration can be attributed to the model or factors considered, indicating a limited predictive ability. Conversely, a value of 0.75661 indicates that approximately 75.66 % of the variability in actual duration is explained by the model, reflecting a moderate level of predictive success. The most substantial explanatory power is seen with a coefficient of determination of 0.999973, suggesting that almost all (99.9973 %) of the observed variability in actual duration is accounted for by the model or factors, indicating a highly accurate predictive capability

4.2. Validation of Results

It is crucial to validate the generated model before its application in the field. This is one of the essential aspects of the models derived from statistical procedures that can show the validation of prediction models. For this purpose, there are a variety of techniques available for the validation of the data. Among others, the most widely accepted tests used are R^2 and mean absolute percentage error

(MAPE). The MAPE is effectively used to check the proximity of fit to the models and their reliability. To test the closeness of the fit of the models, the percentage error (PE) is determined using the following expression, which is expected to be ±10 percent when considering it quite well (Pokhrel et al., 2021).

$$\text{MAPE} = \frac{1}{n}\sum_{i=1}^{n}\frac{\text{abs}\left(\text{Predicted Duration} - \text{Actual Duration}\right)}{\text{Actual Duration}}\times 100$$

From the calculation of MAPE, 9 % is obtained, which falls within the range of 10 %. So, Bromilow's relation can be considered valid. Furthermore, the most substantial explanatory power is seen with a coefficient of determination of 0.723, suggesting that almost all (72.4 %) of the observed variability in actual duration is accounted for by the model or factors, indicating a high predictive capability of current practiced contract duration method, which only accounts for almost 10 %. The coefficient of determination value ranges from 0.4 to 0.6 for an acceptable model (Pokhrel et al., 2021).

4.3. Comparison of Predicted Time, Actual Time and Intended Time

As shown in Fig. 2, the bar graph visually compares predicted, actual, and intended time durations across various projects, with the x-axis denoting these projects' serial number and the y-axis representing time duration in days. Predicted time (blue bars) reflects anticipated completion times, while actual time (red bars) represents time taken for completion, and intended time (green bars) indicates desired completion durations.

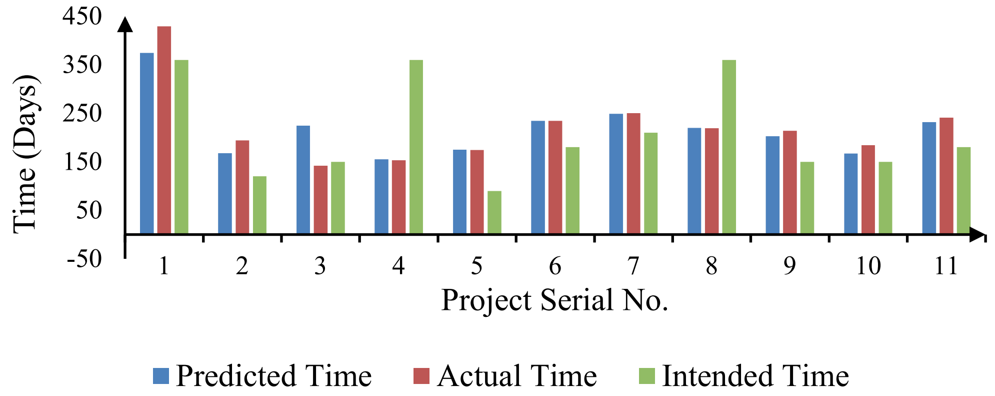

Fig. 2. Comparison of predicted time, actual time and intended time.

Observations reveal that for most categories, actual time exceeds predicted time, suggesting tasks took longer than anticipated. Exceptions occur where actual time falls below predicted time, indicating tasks completed sooner. Intended time is generally shorter than actual and predicted, suggesting initial expectations for shorter durations. Occasional instances show intended time exceeding actual time, possibly due to initial overestimation.

The bar graph suggests that most projects took longer than initially predicted, potentially due to unforeseen challenges, inadequate planning, or time underestimation. However, some categories show efficient completion with shorter actual times. Comparing with the intended time highlights variations between desired outcomes and actual results.

CONCLUSIONS

This study presents a comprehensive analysis of completed government-funded building projects in Gaindakot Municipality, focusing on the relationship between planned time, budgeted cost, and performance-affecting factors. Using both quantitative and qualitative methods, along with the strategic application of the Bromilow time-cost Model, key insights into construction project dynamics were identified.

The quantitative analysis confirmed a strong correlation between project duration and cost, underscoring the importance of time-cost planning in improving project efficiency and minimizing delays and overruns. Qualitative findings revealed critical internal and external factors that hinder performance, highlighting the complexity of construction project management.

The integration and validation of the Bromilow time-cost model further enhanced understanding, offering both analytical precision and practical relevance. Its low mean absolute percentage error (MAPE) confirms its effectiveness as a tool for forecasting and decision-making.

While some limitations exist, this study provides valuable guidance for stakeholders aiming to improve project outcomes, increase community satisfaction, and support sustainable development. The findings and validated model offer a practical framework for future construction initiatives in the Gaindakot Municipality.

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