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Travel Time Reliability of Public Bus Transport: A Case Study of Airport to Narayan Gopal Chowk Route, Kathmandu

by

Santosh Kumar Thapa

A THESIS

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The undersigned certify that they have read and recommended to Institute of Engineering for acceptance, a thesis entitled **"Travel Time Reliability of Public Bus Transport: A Case Study of Airport to Narayan Gopal Chowk Route, Kathmandu"** submitted by Santosh Kumar Thapa in partial fulfillment of the requirement for degree of Master of Science in Transportation Engineering.

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ABSTRACT

The issue of less reliability of public transport in Nepal has drawn significant interest of public authorities, policy makers, planners and researchers and efforts are being made to identify alternative solutions. This study aims to assess the major delay factors affecting travel time reliability of public bus transport, specifically within the context of a case study route between Airport and Narayan Gopal Chowk in Kathmandu. Planning time is used as a measure of the travel time reliability and the assessment is conducted through development of a planning time model. Additionally, the study includes a comparative analysis of the travel time reliability among different bus service providers operating on the case study route. On board technique was adopted to collect the data.

The comparison of travel time reliability among various bus service providers was conducted using an Analysis of Variance (ANOVA) test. The result of ANOVA and post hoc analysis concluded that Khwopa Yatayat has the highest travel time reliability, while Mahanagar Yatayat exhibits the least travel time reliability among the studied four bus service providers at 10% level of significance. Planning time was modelled as a function of the mean travel time and different unexpected delays using the multiple linear regression analysis technique in the SPSS software. Seven different types of unexpected delays i.e., unexpected delay at bus stop, unexpected delay due to stopping at undefined curb stop, unexpected delay at intersection, unexpected delay due to access road, unexpected delay at mid-block due to pedestrian crossing, unexpected delay at mid-block due to u-turning of vehicle, unexpected delay at mid-block due to friction were considered. The final regression model shows that the planning time is significantly dependent on the mean travel time, and unexpected delays i.e., unexpected delay at bus stop, unexpected delay at intersection, unexpected delay due to access road, unexpected delay at mid-block due to friction. The R-square of final model obtained was 0.966. The MAPE value for the developed model was determined to be 8.571 % indicating its potential to predict planning time with high accuracy for selected study route.

Keywords: *Travel time reliability, planning time, unexpected delays, regression model*

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LIST OF SYMBOLES

PT	Planning Time
MTT	Mean Travel Time
BT	Buffer Time
PTI	Planning Time Index
FFTT	Free Flow Travel Time
D_{bs}	Unexpected Delay at Bus Stop
D_{ucs}	Unexpected Delay due to Stopping at Undefined Curb Stop
D_i	Unexpected Delay at Intersection
D_{ar}	Unexpected Delay at Access Road
D_{pc}	Unexpected Delay at Mid-Block Section due to Pedestrian Crossing
D_{ut}	Unexpected Delay at Mid-Block Section due to U-Turning of Vehicle
D_f	Unexpected Delay at Mid-Block Section due to Friction

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LIST OF ABBEREVIATION

FHWA	Federal Highway Administration
DOTM	Department of Transport Management
KSUTP	Kathmandu Sustainable Urban Transport Project
ADB	Asian Development Bank
AVL	Automatic Vehicle Location
ANOVA	Analysis of Variance
MAPE	Mean Absolute Percentage Error

CHAPTER 1: INTRODUCTION

1.1 Background

Public transport refers to a collective passenger transportation service encompassing various modes such as tempos, buses, micro buses, trolley buses, and trains available to any individual and following fixed routes. The provision of public transportation is considered a public service. In Kathmandu, the exclusive cooperative public transportation system is represented by Sajha Yatayat, while numerous private companies also operate various public transportation options such as tempos, taxis, buses and microbuses. Access to public transportation is open to everyone, with services running along designated routes and charging predetermined fares.

The Kathmandu Valley features 27 bus lines within the valley and around 166 city routes, inclusive of bus, microbus and tempo services, primarily along the ring road (Manandhar, 2023). According to statistics from the Department of Transport Management (DOTM, 2018) reveal that only 2.5% of registered vehicles in the Kathmandu valley belong to the public transport category, with 78.5% of those vehicles being two-wheelers. The majority, accounting for 97.5% of the total registered transportation fleet, consists of private, government, and diplomat-owned automobiles (DOTM, 2018).

The diminishing preference for the public transportation system in the Kathmandu valley has been a longstanding issue, attributed to factors such as uncontrolled urbanization, increased motorization, inadequate transit infrastructure, and diminished reliability. The Asian Development Bank (ADB) and the Government of Nepal collaborated on the Kathmandu Sustainable Urban Transport Project (KSUTP), which aimed at ensuring sustainable, secure and efficient urban transport systems and thus strengthen the quality of urban life in the Kathmandu valley. Through implementing into action, four distinct components namely improving and modernizing public transportation, enhancing traffic management, strengthening walkability in the city centre and enhancing air quality monitoring’s, KSUTP aimed to achieve its primary goal (ADB,2019). KSUTP had chosen the Sinamangal-New Buspark route, which is approximately 9 km long, as its pilot route in order to improve reliability.

The lack of reliability in the public transportation system may compel commuters to choose personal vehicles, primarily motorcycles and cars. The increase in these smaller vehicles, sharing routes with larger ones, not only leads to an increase in congestion but also diminishes overall reliability. Hence, it becomes imperative to maintain the public transport system at an optimal level of reliability (Sen, 2019).Thus, this research focuses on the performance of public transport, particularly buses, employing measures of travel time reliability.

1.2 Problem Statement

The escalation of vehicle numbers and the resulting traffic congestion are typical features of urbanization and city life in developing nations such as Nepal. The public transportation system in the Kathmandu valley operates through multiple operators, lacking a well-defined time schedule, interconnectivity, designated bus stations and standardized fare structures. Consequently, the public perceives public transport as an unreliable mode of transportation.

Commuters often endure long and frustrating journeys when using public transportation due to poor transport service. Traffic congestion on roads can result in delays, posing challenges for public transport vehicles to arrive at their destinations punctually on time. The lack of consistent regulations and enforcement can result in service irregularities, impacting the reliability of public transport operations. Many transport companies attempt to adhere to scheduled departure and arrival times but they frequently encounter significant obstacles such as heavy traffic, crash incidents and other unforeseen events making it challenging to meet the expected reliability. The reliability of public transport systems is of great important to most public transport users as unreliability can lead to additional waiting time, arrivals either too early or too late at their destinations and missed connections. These disruptions can significantly increase passenger stress and discomfort.

The issue of less reliability of public transport in Kathmandu has drawn significant interest of public authorities, policy makers, planners and researchers, and efforts have been made to identify alternative solutions. Public transport users, operators and the community emphasize that a key factor in evaluating the quality of a public transportation system is its reliability. Thus, the identification of significant factors that contribute to the fluctuation in travel time reliability of the public transportation is of utmost importance and can provide valuation insights to researchers, planners and policy makers.

The definition of travel time reliability, as outlined by the Florida Department of Transportation (2011), pertains to the percentage of travel time that does not exceed the anticipated travel time with an acceptable additional unexpected time. Iida (1999) has approached the concept from a probabilistic perspective, defining it as the probability of a commuter successfully reaching at their destination within a designated time frame. The United States Federal Highway Administration (FHWA) characterizes travel time reliability as the consistency or predictability in travel times, measured across different times of the day or from day-to-day. Essentially, travel time reliability measures the extent of unexpected delays. The FHWA recommends a straight forward measure of travel time reliability using the 90^{th} or 95^{th} percentile travel times, namely planning time for specific routes or trips, indicating the severity of delays on peak travel days. According to the FHWA, these percentile travel times, expressed with minutes and seconds, are designed to be easily understood by travelers familiar with their routes. Therefore, this study uses planning time as a measure of travel time reliability.

1.3 Objective of Study

The main objective of this study is to assess the major delay factors affecting travel time reliability of public bus transport, specifically within the context of a case study route between Airport and Narayan Gopal Chowk in Kathmandu. The specific objectives include:

1) To compare the travel time reliability of different bus service providers of Airport to Narayan Gopal Chowk Route, Kathmandu.
2) To develop a planning time model for public bus transport taking into account the selected study route to identify the major delay factors influencing the reliability.

1.4 Scope of Study

The study aims to focus on one of the busiest routes of Kathmandu Valley namely Airport to Narayan Gopal Chowk route for the study area. The scope of this study is as below:

1) Comparison of travel time reliability of different bus service providers of Airport to Narayan Gopal Chowk route, Kathmandu with respect to planning time using Analysis of Variance (ANOVA) test.
2) Development of multilinear regression model for planning time of selected study route.
3) Validation of multilinear regression model by Lewis's scale of interpretation.
4) Identification of significant delay factors affecting travel time reliability.

1.5 Limitation of Study

The thesis report was prepared under following limitations:

1) This study is limited to measurement of travel time reliability of selected case study bus route only.
2) The data was collected from 8:30-11:30 AM for six working days for model development. Additional data were collected for validation of model for five days within the same time frame.
3) Automatic Vehicle Location (AVL) data was not available so on-board data collection technique was followed.

1.6 Organization of Report

This thesis report comprises of six chapters as below:

Chapter 1: Introduction: This chapter provides a comprehensive overview including public transport, the current state of public transport in Nepal, challenges faced by the public transport sector in Nepal, the concept of travel time reliability in public bus transport, the problem statement of the thesis work, study objectives, scope and limitations of study. The background section delves into the understanding of the public transportation system, the count of registered vehicles in Nepal, the concept of travel time reliability and the necessity for ensuring travel time reliability.

Chapter 2: Literature Review: This chapter introduces the concept of travel time reliability and reviews existing literature on the subject within the context of Nepal. It also covers recommended parameters for assessing travel time reliability, methods for measurement and modeling of travel time reliability. The identification of factors influencing travel time reliability is based on the findings from the literature review presented in this chapter.

Chapter 3: Methodology: This chapter provides framework of research work, the steps and procedure followed in the selection of the study area, data collection and the extraction process. It also presents the various travel time and delay variables considered in the study and discusses the details of the methodology adopted for comparing travel time reliability and modeling it**.**

Chapter 4: Result and Discussion: The chapter 4 presents result of data analysis, comparison of travel time reliability of different bus service providers, and multiple linear regression. This chapter also discuss about the accuracy of developed planning time model for travel time reliability.

Chapter 5: Conclusion and Recommendation: The chapter 5 summarizes the results of various tests and concludes this study based on the observed results. This section also includes some recommendations for further study on travel time reliability.

CHAPTER 2: LITERATURE REVIEW

2.1 Studies on Reliability of Public Transport in Nepal

Mishra et al. (2020) conducted a study related to operational evaluation of public transportation in Kathmandu, Nepal, specifically focusing on the Kalanki-Kalimati-Tripureshwor-Bhotahity section, covering a distance of 6700 m in forward and 6200 m backward in backward direction. The research utilized economic indicators such as the benefit-cost ratio and rate of return as performance indicators, while service indicators included running time, journey time, running speed, journey speed, running index, passenger waiting index, bus punctuality and accessibility index. The chosen modes of public transport for analysis were Sajha Yatayat, private buses and microbuses. The authors conducted a scheduled questionnaire survey with 94 respondents, revealing that 21.27% expressed dissatisfaction with Sajha Yatayat, buses, and microbuses. Their conclusion was that among the three chosen modes of public transport on the study route namely Sajha Yatayat, buses and microbuses, Sajha Yatayat has superior performance with the performance order being in a decreasing sequence from Sajha Yatayat to buses and then microbuses.

Gautam and Marsani (2020) mentioned that the economic significance of travel time in Nepal, particularly in Kathmandu valley, is underestimated. Their study specifically concentrated on assessing the importance of travel time and the associated reliability for commuters in the Kathmandu Valley. Before gathering data through the stated preference method, a perception survey was conducted. The researchers utilized a Multinomial Logit model for the data to estimate the value of travel time.

Karki and Shahi (2019) evaluated the quality of public transport services by using various indicators, including waiting time, walking distances, frequency during peak and off-peak hours, route changes, fares, and staff behavior. According to their data analysis, the service quality was found to be poor for peak hour service frequency and service reliability, whereas cleanliness, information provision, and waiting time exhibited an average service quality. The researchers recommended enhancing the service reliability of public transport as a crucial measure to boost passenger satisfaction.

Aryal et al. (2022) conducted a study on the demand for public transport services in Nepal, specifically focusing on Kathmandu, a highly congested urban area in a developing country. The research aimed to assess the level of demand by examining various factors. The researchers conducted a choice-based conjoint experiment using five attributes: mode of transportation, waiting time, one-way fare per km, commuting time per km, and payment method. The findings indicated a negative perception among respondents towards the most widely used modes of transport in Kathmandu. The results highlighted user dissatisfaction with the current state of public transportation.

2.2 Previous Studies on Travel Time Reliability

Karami et al. (2021) had analyzed the features of the road network in Kota Bandar Lampung, Lampung, Sumatera, Indonesia, with regard to 95% travel time reliability. The buffer time method was adopted to assess the features of travel time reliability. The impact of planning time and free-flow travel time on average journey time, was represented by developing a regression equation.

Sen et al. (2019) had carried out a study to determine the 95% travel time reliability of various public transportation modes along a specific route in the Kolkata city in India. The state government bus, private bus and minibus in-vehicle journey time reliability were estimated and then results were compared to metro railway. Their findings indicate that journey time reliability falls between 45 to 65 percent behind of the metro railway's reliability for all bus kinds. In order to provide valuable information on the bus reliability, characteristics such as planning time and planning time index were also calculated. The relationship between reliability and other important traffic measures like waiting time delays and congestion delays has also been investigated.

Ashwini et al. (2023) conducted research on analyzing travel time reliability of a bus route in a limited data set scenario taking a case study of “Tumakuru city, India” to analyze 95% travel time reliability. According to the “National Urban Transport Policy” of the

Government of India, service level benchmarks for urban transport include headway, waiting time, speed, and journey time, which are the reliability factors evaluated for public transportation services. According to their findings, the public transport system faced an unexpected delay time of about 30% of the average travel time and more than twice as much free-flow travel time needs to be scheduled at peak hours and worst situation.

Elhenawy et al. (2018) has suggested modelling travel time with a combination of linear regressions equations. They used two normal components in the suggested model. The first component was used to model the congested regime, whereas the second component was used to model the free-flow regime. Using random forest machine-learning approach, the predictors utilized in the linear regression equation were chosen from the spatiotemporal speed matrix. The experimental results presented in this research demonstrated the model's capacity to effectively anticipate travel time and capture its stochastic nature.

Using link flows that were observed in a road network, Uchida (2015) developed a model for estimating the reliability of travel time that addresses travel demand and traffic capacity as causes of uncertainty. A model estimating stochastic path flows based on observed link flows had been developed to determine the unique travel time reliability.

Tu et al. (2012) has measured reliability of travel time in variety of methods and has identified it as one of the most important markers of the effectiveness of transportation systems. The two ideas of reliability are synthesized: traffic breakdown, which is a sign of travel time instability is considered as a risk, and travel time variability which is an indicator of journey time uncertainty, is considered as a consequence of this risk in this study.

In Taylor and Susilawati (2012), the Burr distribution was recommended valuable model for expressing reliability of travel time. The authors highlighted the algebraic tractability of the Burr distribution, emphasizing its capability to directly compute percentile values. The research introduced the integration of reliability into economic analysis, adopting a method that more accurately captures the characteristics of travel time reliability.

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2.3 Summary of Literature Review

Numerous studies have explored the reliability of travel time in public bus transportation. Mishra et al. (2020) demonstrated that various public transport services exhibit low performance, indicating a lack of reliability in service within the context of Nepal. Gautam and Marsani (2020) emphasized the importance of reliable travel time. Aryal et al. (2022) illustrated that passenger satisfaction with service providers is lacking, leading to decreasing demand. Thus, the collective literature indicates the necessity for enhanced reliability of public transport in Nepal.

Studies in context of Nepal have predominantly addressed the reliability of public transport services in terms of service reliability rather than focusing on the reliability of travel time. The global discourse has increasingly highlighted the significance of travel time reliability. Consequently, this study places a specific emphasis on the travel time reliability of public bus transport, aiming to contribute in literature gap by investigating travel time reliability of bus services on the selected case study route in Kathmandu. The Federal Highway Administration has recommended 90^{th} or 95^{th} percentile travel time reliability, namely planning time. Most research papers conducted on travel time reliability have used 95^{th} percentile travel time reliability. Hence, this study uses planning time based on 95^{th} percentile travel time reliability as a measure of travel time reliability.

CHAPTER 3: METHODOLOGY

3.1 Research Design

The primary focus of this research is to investigate travel time reliability on specific route in Kathmandu valley. Figure 3.1 shows methodological framework of this research.

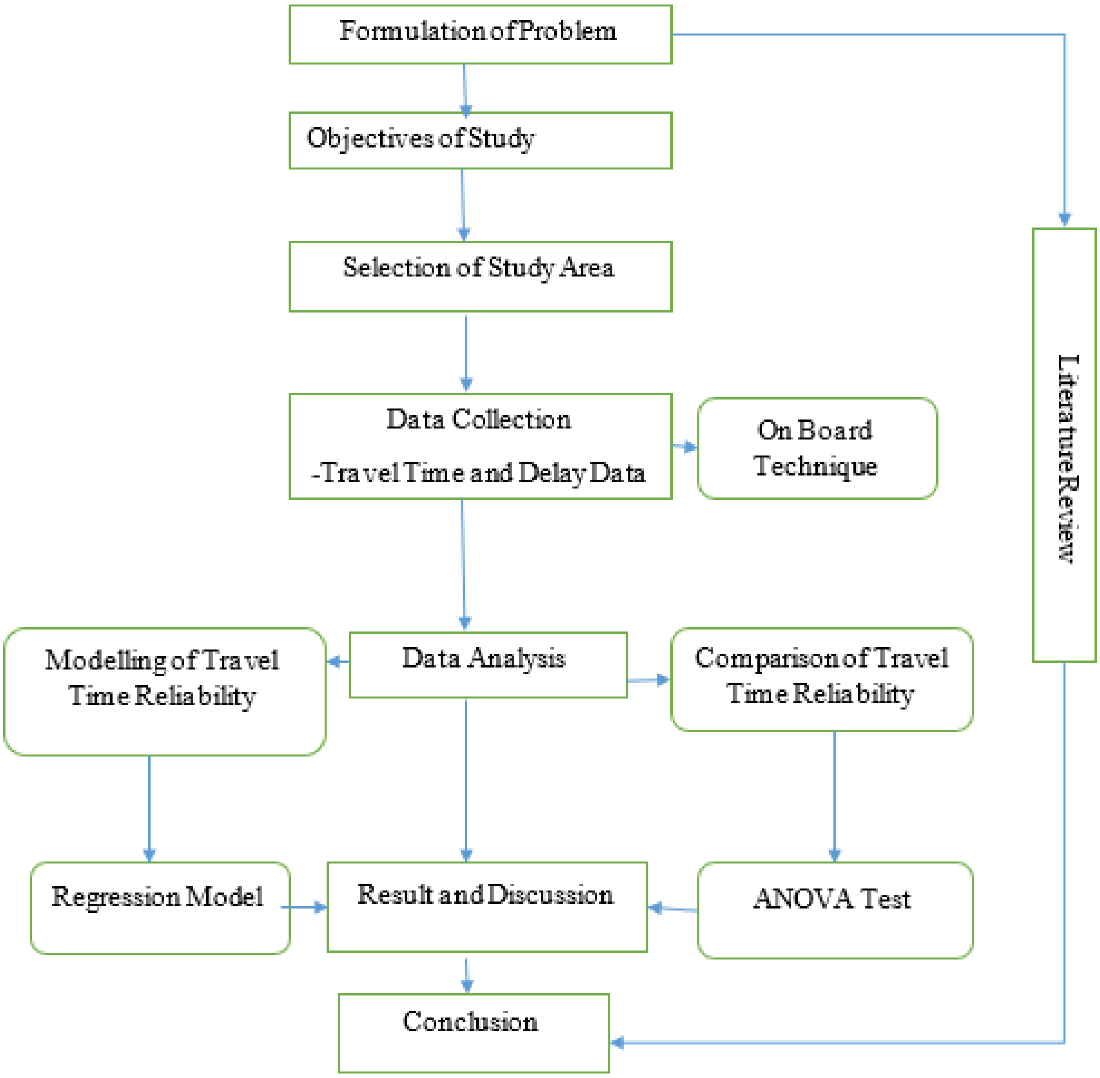

Figure 3. 1: Framework of Research

The methodological steps involve gathering travel time data and different types of delay data for different bus service providers in the selected bus route. Different key parameters such as 95% travel time, mean travel time and different delays were determined from the collected data. To compare travel time reliability among different bus service providers

One Way Analysis of Variance (ANOVA) test was performed in SPSS. A regression model that establishes the relationship for planning time which is a measure of 95% travel time reliability, mean travel time and different unexpected delay was developed to identify the significant delay factors.

3.2 Study Area

Airport to Narayan Gopal Chowk Route as shown in Figure 3.2, is one of the busiest public transport routes in Kathmandu, with multiple bus service providers operating along the way. Therefore, Airport to Narayan Gopal Chowk Route of 5.6 Kilometer (km) was selected as the study route in this research. The study area’s overview and layout are shown in Figure 3.2. The Airport to Narayan Gopal Chowk Road consists of eight bus stops, four unsignalized intersections at Gaushala Chowk, Bageshwari Chowk, Chabahil Chowk and Dhumbarahi Chowk, and a signalized intersection at Mitra Park Chowk. Among the different public service providers operating in the area, four bus service providers Mahanagar Yatayat, Mahasagar Yatayat, Mayur Yatayat and Khwopa Yatayat were selected for this study.

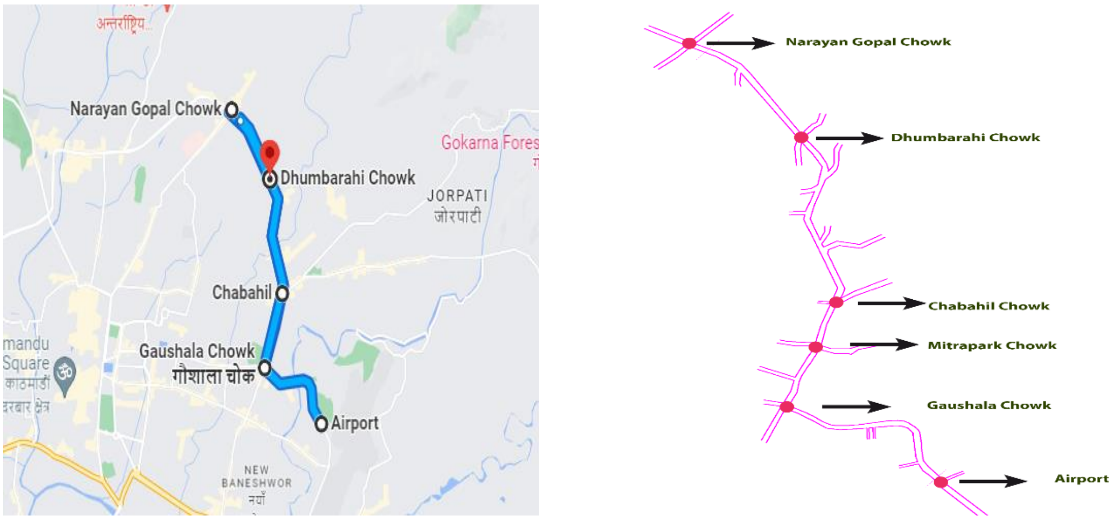

Figure 3.2: Overview and Layout of Study Area

3.3 Modelling of Travel Time Reliability

As mentioned previously, planning time representing 95% travel time reliability, is used as a measure of travel time reliability in this study. Planning Time (PT) refers to the total time duration required to plan for an on-time arrival at the destination that is equal to or less than 95% of the observed sample travel times and is the function of mean travel time and buffer time as shown in Equation (3.1). Higher the value of planning time, lower is the reliability of mode of transport and vice versa (FHWA, 2006).

$$PT = f(\ MTT, BT\ ) \tag{3.1}$$

Where,

PT: Planning Time

MTT: Mean Travel Time

BT: Buffer Time

Mean travel time refers to the average travel time between origin to destination excluding the unexpected delays. Therefore, it is the sum of running time and expected stopped delay experienced by the vehicle. Buffer time refers to the unexpected delays or interruptions during the journey (Gopi et al., 2014). According to Karami (2021), buffer time refers to an extra time for unexpected delay.

3.3.1 Delay Types

Following discusses the different types of expected and unexpected delays considered in this study. These delay types were identified through field experiences and relevant literatures.

3.3.1.1 Delay at Bus Stop

Delay at bus stop has been categorized into expected and unexpected delay as discussed below:

i. Expected Delay at Bus Stop

Delay at bus stop refers to amount of time a bus spends at a bus stop before it resumes its route. Expected delays at bus stop are related to time needed for boarding and alighting of individual passengers at designated bus stops only (Sen et al., 2019). The expected delay at bus stop in this study is defined as the amount of time for picking and dropping of passengers including opening and closing of bus doors when bus heads in to the bus stop and when it reenters to the main traffic stream similar to that in Arhin et.al. (2016) and Huo (2018). According to Arhin et al. (2016), this time for a single bus stop during morning and evening peak hours ranges between 49-51 secs. Field survey during free flow travel time at 6:00 AM in the morning along the study route also revealed an average stop time at a single bus stop time of 45.47 seconds which is near to value suggested by Arhin et al. (2016). Hence, the expected delay at a single bus stop in this study is assumed to be 50 secs.

ii. Unexpected Delay at Bus Stop (D_{bs})

In the context of Nepal, there is a tendency for bus drivers to keep on waiting at bus stops to pick up more passenger. Hence, in this study, the unexpected delay at a bus stop (D_{bs}) is defined as the duration of time a bus spends at a designated bus stop exceeding the expected 50 seconds required for boarding, alighting, opening and closing of doors. This time span extends from the moment the bus arrives at the bus stop until it reenters the main traffic stream.

iii. Unexpected Delay due to Stopping at Undefined Curb Stop (D_{ucs})

Curb side bus stops use a marked portion of the through-traffic lanes for the boarding and alighting of passengers (Liu, 2020). Therefore, locations used for picking and dropping of passengers but lacking official bus stop signage are termed as undefined curb stop in this study. There are several such undefined curb stops along the public transport route in Kathmandu (Shrestha, 2023). Thus, unexpected delay due to stopping at undefined curb stop in this study as illustrated in Figure 3.3 refers to the amount of time that a bus spends for alighting and boarding of passengers at the curb side of the road without bus stop signage.

Figure 3.3: Unexpected Delay due to Stopping at Undefined Curb Stop

3.3.1.2 Delay at Intersection

Delay at intersection has been categorized as expected and unexpected delay as below:

i. Expected Delay at Intersection

In signalized intersections, a fixed number of approaches shares space alternatively for a pre-defined time interval as per the phasing scheme used (Gupta, 2020). Signal delay is defined as the vehicle coming to a halt within the 'stop' line due to the influence of a signal, resulting in a delay in travel time (Sen et al., 2019). The signal delay has been categorized as expected delay because it is a planned and predictable part of the traffic control system as well as drivers. Drivers know that they will have to wait for their turn when the signal is red for their direction, and this waiting time is part of the expected travel experience. Drivers, passengers and transportation planners take it into account when making travel decisions. Thus, expected delay at intersection in this study is defined as delay due to signal similar to that defined by Sen et al. (2019).

ii. Unexpected Delay at Intersection (D_i)

The delay at unsignalized intersection has been categorized as unexpected delay because it lacks predictable traffic signal cycle. Thus, the unexpected delay at intersection in this study refers to the amount of time that a bus spends at unsignalized intersection due to reasons such as high traffic volume, pedestrian crossing, and U-turning of vehicle.

3.3.1.3 Unexpected Delay due to Access Road (D_{ar})

Unexpected delay at access road in this study as illustrated in Figure 3.4 refers to the amount of time lost due to vehicles joining the main road from the access road in the same direction, right turning of vehicle from the access road to the main road, vehicle leaving the main road to the access road, right turning of vehicle from the main road to the access road as described by Boneson (1998). All roads other than those in the major intersections are considered as access roads in this study.

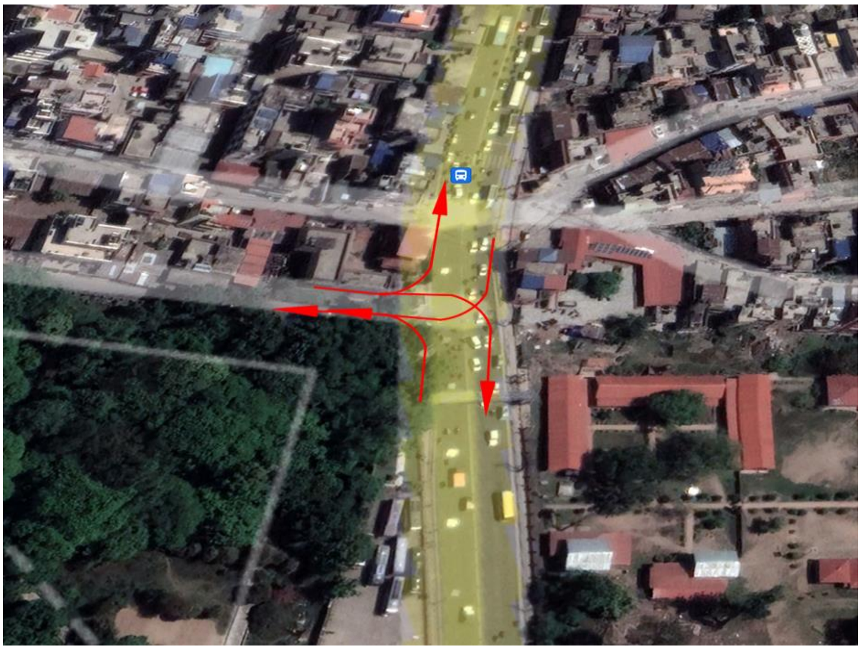

Figure 3.4: Unexpected Delay at Access Road

3.3.1.4 Delay at Mid-Block Section

The delay at mid-block section is termed as unexpected delay and are further classified as follows:

i. Unexpected Delay at Mid-Block due to Pedestrian Crossing (D_{pc})

In Nepalese urban road sections, pedestrians frequently cross the road without using a zebra cross at the midblock part. In order to avoid conflict, pedestrians generally employ force gaps to cross the road and compel approaching vehicles to alter their path or apply their brakes. As stated in Golakiyaa (2019), such pedestrian activity disrupts traffic flow and eventually causes delays in the movement of vehicles. Thus, the unexpected delay at mid-block section due to pedestrian crossing in this study as illustrated in Figure 3.5 is measured as stopped delay of vehicle due to crossing of pedestrian without use of zebra cross (Marisamynathana and Vedagirib, 2013).

Figure 3.5: Unexpected Delay at Mid-Block due to Pedestrian Crossing

ii. Unexpected Delay at Mid-Block due to U- Turning of Vehicle (D_{ut})

The U-turning operation creates disturbance to through vehicles in opposite direction. In most cases, it is observed that a larger radius is required for vehicles to U- turn which increases the delay (Gupta et al., 2018). Thus, unexpected delay due to U- turning at mid-block sections in this study as illustrated in Figure 3.6 is measured as stopped delay of vehicles due to U- turning of vehicle from opposite direction similar to that mentioned by Reid (1967).

Figure 3.6: Unexpected Delay at Mid-Block due to U- Turning of Vehicle

iii. Unexpected Delay at Mid-Block due to Friction (D_f)

Activities taking place on the sides of the road as well as inside the road itself are referred as frictions because they obstruct the flow of traffic on the designated path (Irawati, 2015). Unexpected delay at mid-block due to friction in this study is defined as the delays associated due to high traffic volume, illegal parking at the road side, street vendors in the roadside and so on. Unexpected delay at mid-block due to friction in this study is measured as the amount of stopped delay due to side friction and internal friction activities defined previously similar to that stated in Mahendra et al. (2021).

3.3.2 Model Development

As discussed, previously, planning time is the function of mean travel time and buffer time. Likewise, the buffer time is the function of unexpected delays. Therefore, the planning time is the function of mean travel time and unexpected delays in the route as shown in Equation (3.2).

$$PT = f\,(MTT, D_{bs}, D_{ucs}, D_i, D_{ar}, D_{pc}, D_{ut}, D_f) \qquad (3.2)$$

Where,

PT: Planning time

MTT: Mean travel time

D_{bs}: Unexpected delay at bus stop

D_{ucs}: Unexpected delay due to stopping at undefined curb stop

D_i: Unexpected delay at intersection

D_{ar}: Unexpected delay at access road

D_{pc}: Unexpected delay at mid-block due to pedestrian crossing

D_{ut}: Unexpected delay at mid-block due to U-turning of vehicles

D_f: Unexpected delay at mid-block due to friction

3.3.2.1 Multiple Linear Regression

Multiple linear regression analysis is used to model the relationship between planning time (PT) and the independent variables, mean travel time (MTT) and different unexpected delays i.e., unexpected delay at bus stop (D_{bs}), unexpected delay due to stopping at undefined curb stop (D_{ucs}), unexpected delay at intersection (D_i), unexpected delay at access road (D_{ar}), unexpected delay at mid-block due to pedestrian crossing (D_{pc}), unexpected delay at mid-block due to u turning of vehicle (D_{ut}), unexpected delay at mid-block due to friction (D_f).

Multiple linear regression a primary form of regression modeling which is used to model the relationship of a dependent variable with two or more independent variables. The application of Statistical Packages for Social Sciences (SPSS) facilitates the modeling of multiple linear regression providing the R-square value. R-square value is also referred to as the coefficient of determination. The R-square is a widely used statistic for evaluating the precision of the model. R-square value of close to 1.0 signifies strong relationship between the dependent and independent variables. Variables with a p-value less than 0.05

are said to be significant at a 5% level of significance in the model. The general form of multiple linear regression is shown in the provided Equation (3.3).

$$Y= \beta_0+\beta_1X_1+ \beta_2X_2+ \beta_3X_3+ \beta_4 X_4+ \beta_5 X_5 \tag{3.3}$$

Where,

Y: Dependent variable,

X_1, X_2, X_3, X_4, X_5: Independent variables

$\beta_1, \beta_2, \beta_3, \beta_4, \beta_5$: Coefficient to corresponding independent variables

So, planning time is modeled as a linear function of mean travel time (MTT) and unexpected delays as shown in Equation (3.4).

$$PT= \beta_0+\beta_1MTT+ \beta_2D_{bs}+ \beta_3D_{ucs}+\beta_4D_i+ \beta_5D_{ar}+ \beta_6D_{pc}+ \beta_7D_{ut} +\beta_8D_f \tag{3.4}$$

Where

$\beta_1, \beta_2, \beta_3, \beta 4, \beta 5, \beta_6, \beta_7, \beta_8$: Regression coefficient to corresponding independent variables MTT, D_{bs}, D_{ucs}, D_i, D_{ar}, D_{pc}, D_{ut} and D_f respectively.

3.3.3 Model Validation

Model validation is conducted to assess the accuracy of the developed model by comparing observed field values with the model's predicted values. 80% of collected data are used for development of model whereas 20% of collected data are used for validation of model. Mean Absolute Percentage Error (MAPE) is a commonly used method for evaluating forecast accuracy (Kim, 2016) and used as a measure for validation. The Lewis scale of interpretation is used for explanation of MAPE value. A MAPE value below 10% indicates a model with highly accurate forecasts, while a value between 10% and 20% suggests a model with good forecast accuracy. If the MAPE value lies between 20% and 50%, the model is considered to have reasonable forecast accuracy, whereas a MAPE value exceeding 50% signifies an inaccurate forecast according to the Lewis scale (Omar, 2011). The corresponding interpretations are outlined in Table 3.1.

Table 3. 1: Lewis Scale of Interpretation

S. N.	MAPE	Forecast Accuracy
1	Less than 10%	Highly accurate forecast
2	10 to 20%	Good forecast
3	20 to 50 %	Reasonable forecast
4	Greater than 50%	Inaccurate forecast

3.4 Comparison of Travel Time Reliability

The travel time reliability of different bus service providers is compared with respect to planning time discussed previously and planning time index another measure of travel time reliability. The planning time index is the ratio of planning time to free-flow travel time as given in Equation (3.5). Planning time index indicates the planning time at any time of the day with respect to free flow traffic condition. The higher the value of planning time and planning time index, the less reliable is the mode of transport and vice versa.

$$\mathrm{PTI} = \mathrm{PT}/\mathrm{FFFT} \tag{3.5}$$

Where,

PTI: Planning Time Index

PT: Planning Time

FFTT: Free -Flow Travel Time

3.4.1 One Way Analysis of Variance (ANOVA) Test

ANOVA test was conducted with hypothesis testing to compare the travel time reliability of different bus service provider of selected study route. ANOVA test is a statistical method that is focused on the comparison of means of multiple samples. It is an expansion of the t-test which was originally designed for two independent samples to accommodate more than two samples. The ANOVA test is adopted to evaluate significant difference among class means by analyzing variances, as outlined by Ostertagova (2013). The F- test is the statistical method used in combination with ANOVA. F-test is a ratio derived from two distinct estimates regarding the potential variation among groups. One estimate is concerned to the expected average difference between groups, while the other estimate is concerned with the average difference due to sample data (Fitzgerald,2000). This conceptual interpretation of the F test is shown in Equation (3.6).

$$F = MST/MSE \tag{3.6}$$

MST refers to mean square between samples whereas MSE refers to mean square within samples. The assumption about the One-way ANOVA is enlisted as below:

- The population, from which the samples are obtained follows a normal distribution.
- The samples are not dependent on each other.
- The variance of sample population is uniform or equal.

Post hoc tests are conducted to assess the statistical significance of differences between group means identified after conducting ANOVA, which initially indicates an overall difference among the groups.

3.5 Sampling Size

The rule of thumb has been to use ten to twenty cases for each independent variable. Green (1991) has proposed two variations for consideration of dependent variable in multiple linear regression. He has proposed minimum sample size to be greater or equal to fifty plus eight times number of independent variables (Neupane, 2020). The sampling has been done based upon these two criteria i.e., more than 20 times number of independent variables. In this study, there are eight independent variables. So, sampling size was taken maximum of twenty times independent variable and fifty plus eight times number of independent variables. In this thesis work, more than 360 samples of data were collected in total for selected four bus service providers to meet the sampling criteria.

3.6 Data Collection

On board technique was adopted to collect the data. Due to infeasibility of data collection by a single person, enumerators (Civil Sub-Engineers and Civil Engineering Students) were hired. In this method, surveyors rode on selected bus service providers along the study route, utilizing a stopwatch to record various delays and travel times. Enumerators were trained to collect the data by boarding and giving instructions about different types of delay of selected bus service providers of selected study route at first.

Time of the beginning of the journey in hour, minute and second at the origin was noted. The different types of delays data were recorded using stopwatch in minute and second by each enumerator during the journey time in each journey. The end time was noted down at the destination in hour, minute and second. The same process was followed in the reverse direction too. From this, the travel time taken by the buses of Mahanagar Yatayat, Mahasagar Yatayat, Mayur Yatayat and Khwopa Yatayat of Airport to Narayan Gopal Chowk Road were obtained. Along with travel duration, different delays such as bus stop delay, intersection delay, delay due to access road, delay at mid-block sections due to pedestrian crossing, vehicle U-turning and friction were obtained too. The data were collected from 8:30-11:30 AM for six days during morning peak hour for development of model. Additional data were collected for validation of model from 8:30 to 11:30 AM for five days. The measurement of free flow travel time involved observing the duration taken by chosen bus service providers on the Airport to Narayan Gopal Chowk route at 6 am in the morning. The study did not include public holidays and Saturdays.

3.7 Data Extraction

The data obtained were input on spreadsheet for further processing. The data were classified per 30 min interval of departure time i.e., 8:30-9:00 AM till 11:00-11:30 AM for each bus service providers. For calculating 95% travel time reliability, mean travel time and average delay, seven data of same departure time interval for each bus service provider were grouped together. Therefore, a total of 357 data records were used to obtain 51 set of planning time data, mean travel time and average delay data which were then used for model development and validation. The planning time was calculated for 95% travel time reliability as a 95 percentile for a group of seven data. Similarly, the mean travel time and the delay time were calculated as average for a group of seven data. Thus, forty-one set of data obtained from 287 data records were used for development of model whereas nine set of data obtained from 63 data records were used for validation of model.

CHAPTER 4: RESULT AND DISCUSSION

4.1 Travel Time Reliability of the Bus Service Providers

The overall status of travel time reliability of the four bus service providers in terms of planning time and planning time index are discussed below.

4.1.1 Planning Time of the Bus Service Providers

The descriptive statistical analysis value of planning time of four bus service providers i.e., Mahasagar Yatayat, Mahanagar Yatayat, Mayur Yatayat and Khwopa Yatayat are summarized in the Table 4.1.

Table 4.1:Mean Planning Time

Bus Service Providers	Mean Planning Time (Min)	Standard Deviation (Min)
Mahasagar Yatayat	34.408	4.502
Mahanagar Yatayat	37.920	4.615
Mayur Yatayat	37.751	6.056
Khwopa Yatayat	32.759	4.264

The descriptive statistics values shows that Mahasagar Yatayat has mean planning time of 34.408 minutes with standard deviation 4.502 minutes, Mahanagar Yatayat has mean planning time of 37.920 minutes with standard deviation 4.615 minutes, Mayur Yatayat has mean planning time of 37.751 minutes with standard deviation 6.056 minutes and Khwopa Yatayat has mean planning time of 32.759 minutes with standard deviation 4.264 minutes. The descriptive statistics values shows that Mahanagar Yatayat has maximum mean planning time of 37.920 minutes with standard deviation 4.615 minutes and Khwopa Yatayat has minimum mean planning time of 32.759 minutes with standard deviation 4.264 minutes.

4.1.2 Mean Travel Time of Bus Service Providers

The descriptive statistical analysis value of mean travel time of four bus service providers i.e., Mahasagar Yatayat, Mahanagar Yatayat, Mayur Yatayat and Khwopa Yatayat are presented in the Table 4.2.

Table 4.2: Average Mean Travel Time (Min)

Bus Service Providers	Mean Travel Time (MTT)	Standard Deviation
Mahasagar Yatayat	23.664	1.786
Mahanagar Yatayat	25.038	2.574
Mayur Yatayat	23.384	5.086
Khwopa Yatayat	22.680	1.051

The descriptive statistics values shows that Mahasagar Yatayat has average mean travel time of 23.664 minutes with standard deviation 1.786 minutes, Mahanagar Yatayat has average mean travel time of 25.038 minutes with standard deviation 2.574 minutes, Mayur Yatayat has average mean travel time of 23.384 minutes with standard deviation 5.086 minutes and Khwopa Yatayat has average mean travel time of 22.680 minutes with standard deviation 1.051 minutes. The descriptive statistics values shows that Mahanagar Yatayat has maximum average mean travel time of 25.038 minutes with standard deviation 2.574 minutes and Khwopa Yatayat has minimum average mean travel time of 22.680 minutes with standard deviation 1.051 minutes as shown in Figure 4.1.

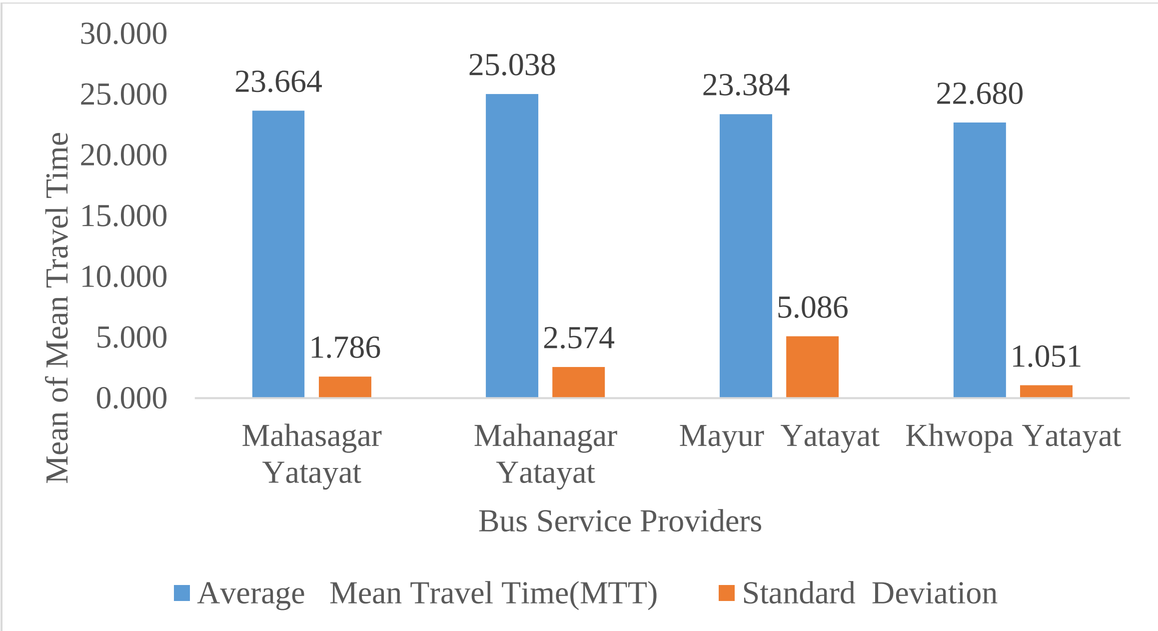

Figure 4.1: Descriptive Statistics of Mean Travel Time

4.1.3 Planning Time Index of the Bus Service Providers

The free-flow travel of public bus transport was found to be 26.37 minute. The descriptive statistics for the planning time index reveal values of 1.305, 1.439, 1.432, and 1.243 for four bus service providers, namely Mahasagar Yatayat, Mahanagar Yatayat, Mayur Yatayat, and Khwopa Yatayat, respectively, as indicated in Table 4.3 and Figure 4.2 respectively.

Table 4.3: Descriptive Statistics of Planning Time Index

Bus Service Providers	Planning Time Index
Mahasagar Yatayat	1.305
Mahanagar Yatayat	1.439
Mayur Yatayat	1.432
Khwopa Yatayat	1.243

The descriptive statistics shows that the planning time of Mahasagar Yatayat is 30.5% more than the free-flow travel time. Likewise, planning time of Mahanagar Yatayat is 43.9% more than the free-flow travel time. Also, the planning time of Mayur Yatayat and Khwopa Yatayat are 43.2% and 24.3% more than the free-flow travel time. This shows Khwopa Yatayat needs minimum of 24.3% more planning time than the free-flow travel time whereas Mahanagar Yatayat requires the maximum of 43.9% more travel time than free-flow travel time.

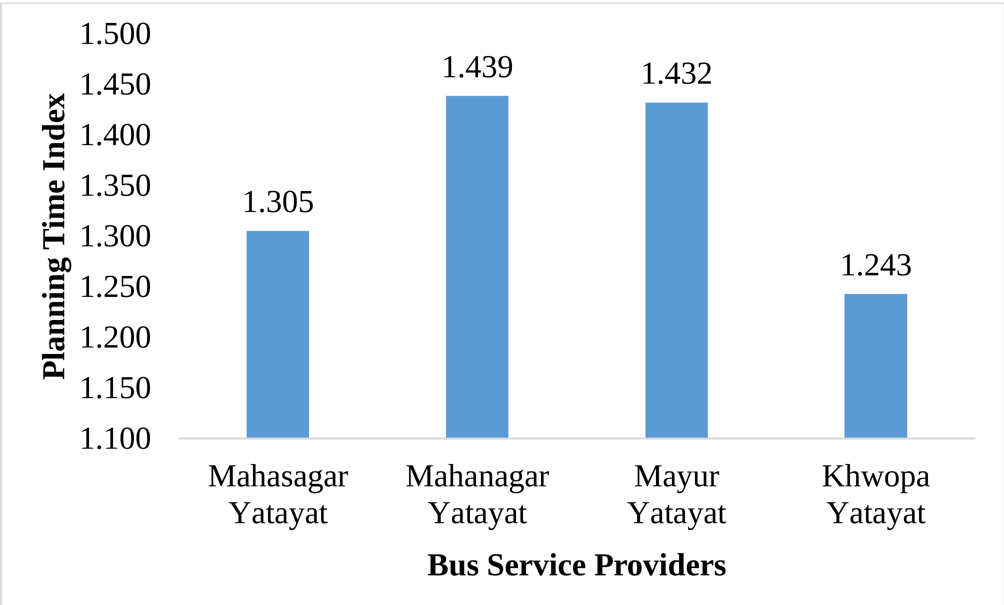

Figure 4.2: Descriptive Statistics of Planning Time Index

4.1.4 Unexpected Delays of the Bus Service Providers

The descriptive statistics of unexpected delay variables of four bus service providers are presented in Table 4.5. This shows that Mayur Yatayat has maximum unexpected delay at bus stop (D_{bs}) of 0.926 min with standard deviation of 0.688 min and Mahanagar Yatayat has least unexpected delay at bus stop (D_{bs}) of 0.509 min with standard deviation of 0.555min. Mahanagar Yatayat has maximum unexpected delay due to stopping at undefined curb stop (D_{ucs}) of 2.415 min with standard deviation of 0.498 min and Khwopa Yatayat has least unexpected delay due to stopping at undefined curb stop(D_{ucs}) of 1.804 min with standard deviation of 0.458min. Mayur Yatayat has maximum unexpected delay at intersection (D_i) of 1.432 min with standard deviation of 1.016 min and Khwopa Yatayat has least unexpected delay at intersection (D_i) of 1.018 min with standard deviation of 0.625 min. Mahasagar Yatayat has maximum unexpected delay at access road (D_{ar}) of 0.803 min with standard deviation of 0.441 min and Khwopa Yatayat has least unexpected delay at access road (D_{ar}) of 0.385 min with standard deviation of 0.228min. Mahasagar Yatayat has maximum unexpected delay at mid-block due to pedestrian crossing (D_{pc}) of 0.251 min with standard deviation of 0.121 min and Mahanagar Yatayat has least unexpected delay at mid-block due to pedestrian crossing (D_{pc}) of 0.1815 min with standard deviation of 0.059min.Mayur Yatayat has maximum unexpected delay at mid-block due to u turning of vehicle (D_{ut}) of 0.207 min with standard deviation of 0.199 min and khwopa Yatayat has least unexpected delay at mid-block due to u turning of vehicle(D_{ut}) of 0.137 min with standard deviation of 0.077min.Mayur Yatayat has maximum unexpected delay at mid-block due to friction(D_f) of 2.026 min with standard deviation of 1.192 min and khwopa Yatayat has least unexpected delay at mid-block due to friction(D_f) of 1.609 min with standard deviation of 0.864min.

4.2 Comparison of Travel Time Reliability of Four Bus Service Providers

The travel time reliability of four bus service providers of selected bus route was compared with respect to planning time. The planning time of Mahasagar Yatayat, Mahanagar Yatayat, Mayur Yatayat and Khwopa Yatayat was compared by conducting ANOVA testing using SPSS software to check if there is significant difference between the travel time reliability of different bus service providers.

The significant value obtained from ANOVA test as shown in Table 4.4 is 0.061, which is more than the significance level of 0.05. This suggests that there is no statistically significant difference in the planning time of four bus service providers at a 5% level of significance. The route is same for all bus service providers and the unexpected delays faced by each bus service providers are of same type for the same route. So, analysis of variance test, shows no significant difference on travel time reliability. Therefore, it can be concluded that there is no significant difference in travel time reliability among different bus service providers at a 5% level of significance.

Table 4.4: ANOVA Result for Comparison of Travel Time Reliability of the Four Bus Service Providers

	Sum of Squares	**df**	**Mean Square**		**F**	**Sig.**
Between Groups	194.502	3	64.834		2.690	0.061
Within Groups	867.799	36	24.106			
Total	1062.301	39				

But the result shows that at 10% level of significance, there is significant difference between travel time reliability of different bus service providers. The results of the post hoc test indicate a significant difference in the mean planning time between Mahanagar Yatayat and Khwopa Yatayat, with a significant value of 0.024 and a mean difference of 5.160 minutes. There is significant difference between mean value of Mayur Yatayat and Khwopa Yatayat ($p=0.029<0.1$) with mean difference of 4.991 minutes. While there is no notable difference between mean value of planning time of Mahasagar Yatayat with Mahanagar Yatayat, Mayur Yatayat and Khwopa Yatayat. The result of ANOVA and post hoc analysis concluded that Khwopa Yatayat has the highest travel time reliability, while Mahanagar Yatayat exhibits the least travel time reliability among the studied four bus service providers at 10% level of significance. The result of post hoc test is presented in Table 4.6.

Table 4.5: Descriptive Statistics of Unexpected Delay Variables of Four Bus Service Providers

Unexpected Delay Variables	Mahasagar Yatayat		Mahanagar Yatayat		Mayur Yatayat		Khwopa Yatayat	
	Mean (Min)	Std. Deviation (Min)	Mean (Min)	Std. Deviation	Mean (Min)	Std. Deviation	Mean (Min)	Std. Deviation
D_{bs}	0.589	0.317	0.509	0.555	0.926	0.688	0.542	0.152
D_{ucs}	2.289	0.487	2.415	0.498	2.217	0.316	1.804	0.458
D_i	1.211	0.728	1.107	0.828	1.432	1.016	1.018	0.625
D_{ar}	0.803	0.441	0.570	0.336	0.620	0.348	0.385	0.228
D_{pc}	0.251	0.121	0.181	0.059	0.218	0.176	0.181	0.113
D_{ut}	0.179	0.143	0.205	0.128	0.207	0.199	0.137	0.077
D_f	1.872	0.924	1.985	0.507	2.026	1.192	1.609	0.864

4.3 Result of Correlation Analysis

Correlation analysis was executed by inputting both the dependent and independent variables into the SPSS software. Table 4.7 shows the result of correlation test. The correlation analysis shows that the maximum correlation value is 0.340 between unexpected delay at mid-block due to u- turning of vehicle (D_{ut}) and unexpected delay at mid-block due to pedestrian crossing (D_{pc}) which is less than 0.5 as shown in table 4.6. So, all independent variables mean travel time (MTT) and different unexpected delays variables i.e., unexpected delay at bus stop (D_{bs}), unexpected delay due to stopping at undefined curb stop (D_{ucs}), unexpected delay at intersection (D_i), unexpected delay at access road (D_{ar}), unexpected delay at mid-block due to pedestrian crossing (D_{pc}), unexpected delay at mid-block due to U-turning of vehicle (D_{ut}), unexpected delay at mid-block due to friction (D_f) were considered for model development.

Table 4. 6: Post Hoc Test Result

Multiple Comparisons				
Dependent Variable:	**Planning time**			
(I)Bus Service Providers	**(J)Bus Service Providers**	**Mean Difference (I-J)**	**Std. Error**	**p-value**
Mahasagar Yatayat	Mahanagar Yatayat	-3.512	2.196	0.118
	Mayur Yatayat	-3.343	2.196	0.137
	Khwopa Yatayat	1.648	2.196	0.458
Mahanagar Yatayat	Mahasagar Yatayat	3.512	2.196	0.118
	Mayur Yatayat	0.168	2.196	0.939
	Khwopa Yatayat	5.160	2.196	**0.024**
Mayur Yatayat	Mahasagar Yatayat	3.343	2.196	0.137
	Mahanagar Yatayat	-0.168	2.196	0.939
	Khwopa Yatayat	4.991	2.196	**0.029**
Khwopa Yatayat	Mahasagar Yatayat	-1.648	2.196	0.458
	Mahanagar Yatayat	-5.160	2.196	**0.024**
	Mayur Yatayat	-4.991	2.196	**0.029**

Table 4. 7: Correlation Matrix

Correlations									
		D_{bs}	D_{ucs}	D_i	D_{ar}	D_{pc}	D_{ut}	D_f	MTT
D_{bs}	Pearson Correlation	1	0.004	-0.009	0.221	-0.001	0.210	0.061	0.296
	Sig. (2-tailed)		0.981	0.958	0.164	0.994	0.187	0.704	0.061
D_{ucs}	Pearson Correlation	0.004	1	0.262	0.117	0.141	0.226	0.062	-0.060
	Sig. (2-tailed)	0.981		0.099	0.468	0.379	0.155	0.702	0.708
D_i	Pearson Correlation	-0.009	0.262	1	-0.006	-0.111	0.212	-0.012	-0.255
	Sig. (2-tailed)	0.958	0.099		0.968	0.488	0.184	0.939	0.108
D_{ar}	Pearson Correlation	0.221	0.117	-0.006	1	0.280	-0.099	0.018	-0.062
	Sig. (2-tailed)	0.164	0.468	0.968		0.076	0.539	0.911	0.701
D_{pc}	Pearson Correlation	-0.001	0.141	-0.111	0.280	1	$.340^{*}$	$.321^{*}$	0.043
	Sig. (2-tailed)	0.994	0.379	0.488	0.076		0.030	0.041	0.787
D_{ut}	Pearson Correlation	0.210	0.226	0.212	-0.099	**.340***	1	0.303	0.151
	Sig. (2-tailed)	0.187	0.155	0.184	0.539	0.030		0.054	0.347
D_f	Pearson Correlation	0.061	0.062	-0.012	0.018	$.321^{*}$	0.303	1	$.331^{*}$
	Sig. (2-tailed)	0.704	0.702	0.939	0.911	0.041	0.054		0.034
MTT	Pearson Correlation	0.296	-0.060	-0.255	-0.062	0.043	0.151	$.331^{*}$	1
	Sig. (2-tailed)	0.061	0.708	0.108	0.701	0.787	0.347	0.034	

4.4 Planning Time Model and Major Delays

The Model was developed through multiple linear regression analysis using SPSS adopting stepwise regression method. Unexpected delay due to stopping at undefined curb stop (D_{ucs}) and unexpected delay at mid-block due to pedestrian crossing (D_{pc}) were found to be insignificant then model was developed by considering significant independent variables only. In the developed model, the constant variable was deemed statistically insignificant, indicating the necessity to set the intercept to zero. Consequently, the model was developed in Excel, keeping the constant/intercept variable as zero.

The independent variables, unexpected delay due to stopping at undefined curb stop (D_{ucs}), unexpected delay at mid-block due to pedestrian crossing (D_{pc}) and unexpected delay due to u-turning of vehicle (D_{ut}) were found to be insignificant as p-value was greater than 0.05 at 5% level of significance. The independent variables, mean travel time (MTT), unexpected delay at bus stop (D_{bs}), unexpected delay at intersection (D_i), unexpected delay at access road (D_{ar}) and unexpected delay at mid-block due to friction (D_f) were found to be significant as p-value was less than 0.05 at 5% level of significance. The coefficient of determination (R^2) of final model obtained was 0.966 as indicated in Table 4.8. The R-square value of 0.966 reveals that 96.6 % variation in planning time can be explained by independent variables.

Table 4.8: Model Summary

Model	R	R Square	Std. Error of the Estimate
1	.997	.966	2.8044

The coefficient of the final model is presented in Table 4.9. The p-value for each independent variable is below 0.05, indicating that each independent variable has a significant relationship with planning time. The equation for the final model of planning time of public bus transport can be seen in Equation (4.1) with significant independent variables mean travel time (MTT), unexpected delay at bus stop (D_{bs}), unexpected delay at intersection (D_i), unexpected delay at access road (D_{ar}) and unexpected delay at mid-block due to friction (D_f).

Mean travel time (MTT), unexpected delay at bus stop (D_{bs}), unexpected delay at intersection (D_i), unexpected delay at access road (D_{ar}) and unexpected delay at mid-block due to friction (D_f) were found to be most significant independent variables affecting planning time.

$$\mathbf{PT(Min) = 1.034 * MTT + 2.246 * D_{bs} + 3.192 * D_i + 3.108 * D_{ar} + 2.009 * D_f} \tag{4.1}$$

The unit increase unexpected delay at bus stop (D_{bs}) increases planning time by 2.246 min, unexpected delay at intersection (D_i) increases planning time by 3.192 min, unexpected delay at access road (D_{ar}) increases planning time by 3.108 min, unexpected delay at mid-block due to friction (D_f) increases planning time by 2.009min.

Table 4.9: Model Coefficients

Variables	Coefficients	Standard Error	t Stat	P-value
Intercept	0	#N/A	#N/A	#N/A
D_{bs}	2.246	0.950	2.365	0.024
D_i	3.192	0.522	6.110	0.000
D_{ar}	3.108	1.203	2.584	0.014
D_f	2.009	0.525	3.826	0.000
MTT	1.034	0.062	16.590	0.000

4.5 Model Validation

Out of the 51 sets of data sets obtained from 357 data records, 41 sets were utilized for development of model whereas 9 sets were used for validation of developed model. Mean Absolute Percentage Error (MAPE) between field observed value and predicted value was calculated as shown in Table 4.10. The plot of field planning time and predicted planning time is as shown in Figure 4.3. MAPE value was found to be 8.571 % as indicated in table 4.10. As Lewis's scale of interpretation states that the Mean Absolute Percentage Error (MAPE) of less than 10% of model indicates highly accurate forecast. Thus, it can be concluded that the developed model is able to predict planning time with highly accurate forecast.

Table 4.10: Results of Validation of Model

S.N.	Delay due to Bus Stop			Delay at Intersection		D_{ar}	Unexpected Delay at Mid-Block			Total Travel Time	Mean Travel Time (MTT)	Field Planning Time (PT)	Predicted Planning Time (PT)	% Change	Mean Absolute Percentage Error (MAPE)
	Expected Delay at Bus Stop	D_{bs}	D_{ucs}	Expected Delay at Intersection	D_i		D_{pc}	D_{ut}	D_f						
	Min	Min	Min	Min	Min	Min	Min	Min	Min	Min	Min	Min	Min		
1	7.063	0.891	2.178	0.322	1.095	0.445	0.094	0.249	0.177	27.767	22.638	29.358	30.647	4.391%	
2	8.811	2.909	1.689	0.141	1.987	0.337	0.067	0.221	0.199	27.950	14.672	31.558	29.498	6.530%	
3	8.072	2.326	1.492	5.694	1.210	0.639	0.238	0.063	0.298	29.802	23.537	34.892	36.012	3.210%	
4	9.736	3.606	1.743	1.119	1.347	0.685	0.115	0.123	0.326	31.443	16.784	35.533	32.543	8.416%	
5	7.055	1.005	2.774	0.136	0.938	0.507	0.035	0.163	0.293	27.814	22.099	30.293	30.271	0.074%	8.571%
6	7.730	1.546	2.624	0.300	1.205	0.252	0.111	0.218	0.254	31.633	25.423	41.933	34.907	16.754%	
7	9.259	3.094	2.334	0.672	1.587	0.225	0.043	0.166	0.499	31.621	23.674	35.408	38.203	7.891%	
8	7.644	1.982	2.081	0.027	1.361	1.018	0.107	0.228	0.360	26.807	19.670	30.150	33.025	9.537%	
9	8.902	2.160	2.514	0.443	1.794	0.214	0.022	0.176	5.723	29.992	14.905	31.707	38.154	20.334%	

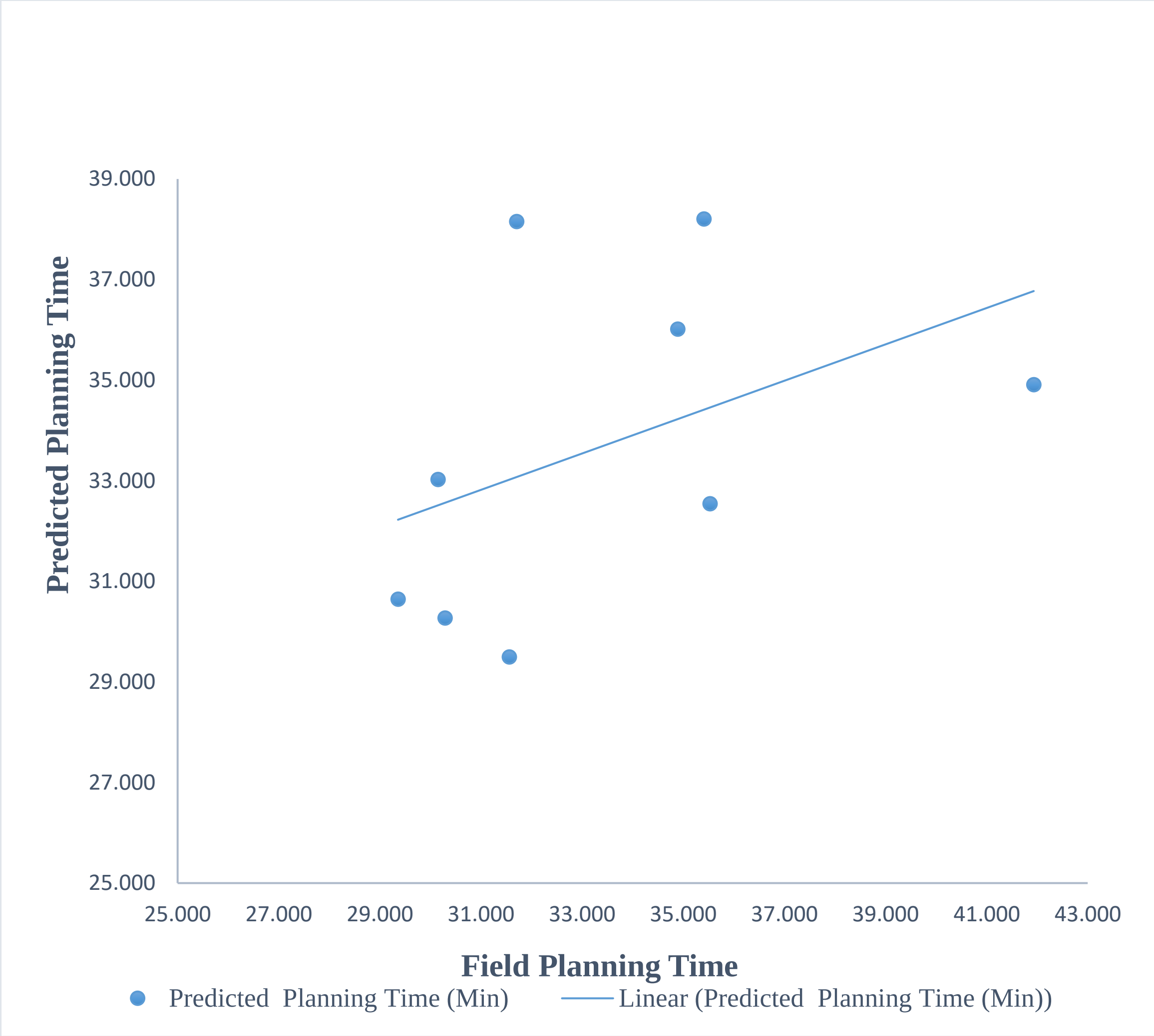

Figure 4.3: Plot of Field Planning Time and Predicted Planning Time

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This study investigates the travel time reliability of four different bus service providers namely Mahasagar Yatayat, Mahanagar Yatayat, Mayur Yatayat and Khwopa Yatayat operational between Airport and Narayan Gopal Chowk route in Kathmandu. The travel time reliability of the service providers was compared in terms of planning time and planning time index. 95% travel time reliability has been considered for calculating planning time. Analysis of Variance (ANOVA) and post hoc test was used to compare the travel time reliability of selected bus service providers. Correlation analysis was used to assess the multi-collinearity between the independent variables. Multiple linear regression analysis technique was carried out to model the planning time using SPSS software and Excel to identify the major delays influencing the travel time reliability. Lewis's scale of interpretation based on Mean Absolute Percentage Error (MAPE) was used for validation of the model.

Based on the test results and analysis, the following conclusion can be drawn:

- The results of ANOVA and post hoc test shows that the planning time Mahanagar and Khwopa Yatayat, Mayur Yatayat and Khwopa Yatayat are significantly different at 10% level of significance. This shows that Khwopa Yatayat has highest travel time reliability whereas Mahanagar Yatayat has least travel time reliability among the four bus service providers.
- The correlation analysis showed a maximum correlation value is 0.340 between unexpected delay at mid-block due to u- turning of vehicle and unexpected delay at mid-block due to pedestrian crossing which is less than 0.5. This signifies there is no strong multi-collinearity between the independent variables.
- The multiple linear regression showed mean travel time, unexpected delay at bus stop, unexpected delay at intersection, unexpected delay at access road, and unexpected delay at mid-block due to friction have significant relation to the planning time. The unit increase in unexpected delay at bus stop, unexpected delay at intersection, unexpected delay at access road, and unexpected delay at mid-block due to friction increases planning time by 2.246 min, 3.192 min, 3.108 min, and 2.009 min, respectively.

- The R-square of final model obtained was 0.966 which reveals that 96.6 % variation in planning time can be explained by these independent variables.
- The MAPE value for the developed model was determined to be 8.571% indicating its potential to predict planning time with high accuracy for selected study route.

5.2 Recommendations

Unexpected delay at bus stop, unexpected delay at intersection, unexpected delay at access road, and unexpected delay at mid-block due to friction were found to be significant delays affecting travel time reliability at 95% confidence limit. Likewise, unexpected delay due to stopping at undefined curb stop and unexpected delay at mid-block due to U-turning were found to be significant delay affecting travel time reliability at 80% confidence limit. The findings from this study recommend the following actions for public authorities, policy makers, and concerned bodies to improve travel time reliability:

- The bus keeps on waiting at the designated bus stop to pick up more passengers which decreases the travel time reliability. Therefore, it is recommended to keep fixed schedule at the designated bus stop to improve travel time reliability.
- The bus used to stop at the undefined curb stop lacking official bus stop signage for boarding and alighting of passengers. Therefore, it is recommended to board and alight passengers from public bus transport at the designated bus stop only to increase travel time reliability.
- The delay is attributed due to frictional activities such as street vendors and unauthorized parking at the roadside. Therefore, it is recommended to regulate frictional activities to enhance travel time reliability.
- The delay is attributed due to U-turning of vehicles. Therefore, it is recommended to regulate U-turning activities of vehicles at the designated location only to improve travel time reliability.

5.3 Direction for Future Work

Study of travel time reliability in this study is limited to bus service providers in only one route, and collection of data from 8:30-11:30 AM for three hours for working days only.

Only the delay factors affecting travel time reliability has been considered in this study. Thus, some of the recommendations for further study are enlisted below:

- Study of travel time reliability of public transport for different times of the day
- Study of travel time reliability with respect to number of passengers boarding and alighting at the designated bus stop.
- Study of factors other than delay factors affecting travel time reliability
- Study of travel time reliability of public transport in other routes

REFERENCES

Manandhar, R. B. ,2023, “Passengers’ Satisfaction towards Service Quality with Public Transportation in Kathmandu Valley”, International Research Journal of MMC (IRJMMC), 4(1), 1-8
https://www.adb.org/projects/44058-013/main

Prajapati, A., Bajracharya, T. R., Bhattarai, N., & Froyen, Y. K. ,2019, “Public Bus Accessibility and its Implications in Energy and Environment: A Case Study of Kathmandu Valley” Journal of the Institute of Engineering, 15(3)

lkubati, M. A., Khalifa, N. A., & Al-barakani, H. A. ,2023, “An overview of public transport reliability studies using a bibliometric analysis”, Ain Shams Engineering Journal, 14(3), 10190

Bates, J., Polak, J., Jones, P. and Cook, A., 2001, "The valuation of reliability for personal travel, “Transportation Research Part 37E, 191-229

FDOT (Florida Department of Transportation), 2011, “SIS bottleneck study (Technical Memorandum No. 2—Methodology to identify bottlenecks)”

Iida, Y. ,1999, “Basic concepts and future directions of road network reliability analysis”, Journal of advanced transportation, 33(2), 125-134

Karki, B., & Shahi, P. B. ,2019, “Assessing the service quality of public transport service: A case of S-5 route in Kathmandu valley”, In Proceedings of IOE Graduate Conference (pp. 739-744)

Elefteriadou, L., & Cui, X. ,2007, “A framework for defining and estimating travel time reliability” (No. 07-1675)

Sen, S., Chowdhury, T., Mitra, A., & Roy, S. K. ,2019, “Assessing travel time reliability of public transport in Kolkata: a case study”, In Advances in Transportation Engineering: Select Proceedings of TRACE 2018 (pp. 21-34). Springer Singapore

Ashwini, B. P., Sumathi, R., & Sudhira, H. S. ,2023, “Analyzing Travel Time Reliability of a Bus Route in a Limited Data Set Scenario: A Case Study”, International Journal of Intelligent Systems and Applications in Engineering, 11(2), 30-39

Taylor, M. A. ,2012, “Modelling travel time reliability with the Burr distribution”, Procedia-Social and Behavioral Sciences, 54, 75-83

Gopi, P., Sachdeva, S. N., & Bharati, A. K. ,2014, “Evaluation of travel time reliability on urban arterial”, International Journal of Engineering Research, 3(6)

Arhin, S., Noel, E., Anderson, M. F., Williams, L., Ribisso, A., & Stinson, R. ,2016, “Optimization of transit total bus stop time models”, Journal of Traffic and Transportation Engineering (English Edition), 3(2), 146-153

Neupane, P. ,2020, “Estimation of Motorcycle Equivalent Unit Using Multiple Linear Regression and Impact of Motorcycle on Saturation Flow Rates (A case study of intersections of Kathmandu valley)”, (Doctoral dissertation, Pulchowk Campus)

Shrestha, A., Pradhananga, R.,2023,"Modelling Delay due to Curb-Side Bus Stops at Signalized Intersection: A Case Study of New Baneshwor Intersection" 2nd International Conference on Integrated Transport for Sustainable Mobility

Marisamynathan, S., & Vedagiri, P.,2013,” Modeling pedestrian delay at signalized intersection crosswalks under mixed traffic condition”, Procedia-social and behavioral sciences, 104, 708-717

Reid, D. H. ,1968, “Delays caused by right-turning vehicles”, Transportation Science, 2(2), 160-171

Mahendra, M., Wicaksono, A., & Djakfar, L. ,2021, “The effect of side friction on delays in one-way urban road sections”, Journal of Southwest Jiaotong University, 56(5)

Karami, M., Herianto, D., Ofrial, S. A., & Yulianti, N.,2021, “Empirical Analysis for Measuring Travel Time Reliability on Road Network”,Civil Engineering Dimension, 23(2), 100-107.

Uchida, K. ,2015, “Travel time reliability estimation model using observed link flows in a road network”, Computer-Aided Civil and Infrastructure Engineering, 30(6), 449-463.

Tu, H., Li, H., Van Lint, H., & van Zuylen, H. ,2012, “Modeling travel time reliability of freeways using risk assessment techniques”, Transportation Research Part A: Policy and Practice, 46(10), 1528-1540.

Elhenawy, M., Hassan, A. A., & Rakha, H. A. ,2018, “Travel time modeling using spatiotemporal speed variation and a mixture of linear regressions”, In Proceedings of the 4th International Conference on Vehicle Technology and Intelligent Transport Systems-Volume 1: VEHITS. Vol. 1. (pp. 113-120). Scitepress.

Mishra, K., Sah, R. C., & Aithal, P. S. ,2020, “Operational Assessment of Public Transport; A Case of Kathmandu, Nepal”, International Journal of Case Studies in Business, IT, and Education (IJCSBE), 4(2), 132-152.

Aryal, T.R., Ichihashi, M. and Kaneko, S., 2022,” How strong is demand for public transport service in Nepal? A case study of Kathmandu using a choice-based conjoint experiment”, Journal of Economic Structures, 11(1), p.29.

www.ops.fhwa.dot.gov/publications/tt_reliability/TTR_Report.htm. Accessed 14 July 2007

Ostertagová, E., & Ostertag, O. ,2013, “Methodology and Application of One-way ANOVA”, American Journal of Mechanical Engineering, 1(7), 256-261.

Giri, M., & Shrestha, P. K. ,2022, “Modelling of Pedestrian Walking Behavior at Foot over bridges”, Proceedings of 12th IOE Graduate Conference

Kafle, S. C., 2020, “OCEM Journal of Management, Technology & Social Science”

Kim, S., & Kim, H. ,2016, “A new metric of absolute percentage error for intermittent demand forecasts”, International Journal of Forecasting, 32(3), 669-679.

Omar, A., & Jaffar, M. M. ,2011, “Comparative Analysis of Geometric Brownian motion Model in Forecasting Syariah Counter in Bursa Malaysia”,

APPENDIX A: Sample of Data Survey Sheet

Field Survey Sheet														
Name of Enumerator														
Types of Delay				Bus Stop Delay			Intersection delay		Delay at access road (D_{ar})	Delay at mid-block			Bus end time	Destination
Date	Name of Public Transport	Origin	Bus start Time	Expected Delay at bus stop	Unexpected Delay at bus stop (D_{bs})	Unexpected delay due to stopping at undefined curb stop (D_{ucs})	Expected delay at intersection	Unexpected delay at intersection (D_i)		due to pedestrian crossing (D_{pc})	due to u turning of vehicle (D_{ut})	due to friction (D_f)		

APPENDIX B: Data of Mahasagar Yatayat

S.N.	Delay at Bus Stop			Delay at Intersection		Unexpected Delay due to Access Road (D_{ar})	Unexpected Delay at Mid-Block			Average Total Travel Time	Mean Travel Time	95% Travel Time
	Expected Delay at Bus Stop	D_{bs}	D_{ucs}	Expected. Delay at intersection	D_i		D_{pc}	D_{ut}	D_f			
	Min	Min	Min	Min	Min	Min	Min	Min	Min	Min	Min	Min
1	6.201	1.014	1.970	0.934	0.670	0.794	0.087	0.056	0.967	28.106	23.632	27.044
2	5.494	0.553	2.124	0.289	0.620	1.211	0.084	0.058	0.267	27.875	24.121	29.033
3	6.081	0.853	1.791	0.693	1.580	0.865	0.268	0.163	1.976	30.268	22.620	33.385
4	5.478	0.012	2.143	0.776	1.048	0.115	0.146	0.263	1.704	28.050	22.618	30.917
5	6.380	0.567	2.217	0.218	0.459	1.227	0.351	0.083	2.224	34.475	27.347	39.317
6	6.237	0.987	3.561	0.569	1.249	0.777	0.265	0.074	1.083	29.744	21.749	33.063
7	5.571	0.400	2.341	1.502	1.260	0.550	0.325	0.515	3.512	35.008	26.106	38.266
8	5.897	0.312	2.340	0.774	2.618	0.441	0.235	0.283	1.968	30.633	22.437	40.563
9	5.250	0.439	2.412	0.959	2.140	0.459	0.283	0.169	2.524	32.043	23.616	35.687
10	5.713	0.755	1.987	0.672	0.464	1.586	0.470	0.124	2.490	30.270	22.393	36.803

APPENDIX C: Data of Mahanagar Yatayat

S. N	Delay at Bus Stop			Delay at Intersection		Unexpected Delay at Access Road (D_{ar})	Delay at Mid-Block			Average Total Travel Time	Mean Travel Time	95% Travel Time
	Expected Delay at Bus Stop	D_{bs}	D_{ucs}	Expected Delay at Intersection	Di		D_{pc}	D_{ut}	D_f			
	Min	Min	Min	Min	Min	Min	Min	Min	Min	Min	Min	Min
1	6.1652	0.3131	2.7472	0.8246	1.0240	0.5842	0.1819	0.2145	1.8017	31.2595	24.3930	36.5300
2	4.6394	0.0000	2.3723	2.6137	0.3646	0.3279	0.1469	0.0577	2.1376	30.2367	24.8297	32.4200
3	5.0029	0.2738	1.8619	0.7789	0.9977	0.4702	0.2107	0.2569	1.6668	32.4420	26.7040	41.1333
4	6.1223	0.1458	1.7791	1.2489	0.5373	0.9484	0.1613	0.1691	2.2213	27.6667	21.7045	31.3833
5	6.6572	0.6993	1.6944	0.6984	0.3717	0.1903	0.1949	0.0562	1.4185	30.6186	25.9934	35.9300
6	6.8547	1.0976	2.5419	2.7375	2.0244	0.2500	0.1203	0.4961	1.3190	37.5500	29.7006	44.6050
7	6.8298	1.8017	2.9696	1.2912	3.0149	1.1143	0.1927	0.2719	2.3957	32.6000	20.8393	45.3033
8	5.4820	0.2857	2.8479	0.5734	0.6122	0.3645	0.0787	0.2035	1.5410	31.4714	25.5380	36.1100
9	6.0655	0.3678	2.3114	0.3667	1.0849	0.4354	0.2452	0.1071	2.7690	34.1690	26.8482	37.9167
10	6.0044	0.1088	3.0228	1.1384	1.0431	1.0180	0.2817	0.2142	2.5809	32.0995	23.8300	37.8633

APPENDIX D: Data of Mayur Yatayat

S. N	Delay at Bus Stop			Delay at Intersection		Dar	Delay at Mid-Block			Average Total Travel Time	Mean Travel Time	95% Travel Time
	Expected Delay at Bus Stop	Dbs	Ducs	Expected Delay at Intersection	Di		Dpc	Dut	Df			
	Min	Min	Min	Min	Min	Min	Min	Min	Min	Min	Min	Min
1	5.870	0.513	1.826	0.285	1.122	0.528	0.232	0.111	1.792	28.257	22.134	32.175
2	6.451	1.049	2.569	0.115	0.743	0.242	0.143	0.072	0.106	26.177	21.254	30.367
3	6.084	0.893	2.187	0.953	2.578	0.503	0.224	0.313	2.468	35.290	26.251	41.562
4	6.889	0.139	2.562	1.166	3.408	0.000	0.000	0.000	0.080	29.058	11.435	29.486
5	5.771	0.384	2.181	1.587	2.753	0.646	0.233	0.123	1.636	34.814	26.858	37.145
6	5.604	0.556	2.056	0.854	1.576	1.100	0.241	0.136	2.594	33.124	24.944	44.780
7	8.518	2.639	1.571	1.415	0.802	1.001	0.040	0.172	2.659	39.123	30.238	47.527
8	5.856	0.892	2.327	0.995	0.789	0.372	0.102	0.124	4.100	32.828	24.121	37.808
9	6.941	1.628	2.257	1.438	0.460	0.637	0.371	0.668	1.983	33.917	25.913	41.127
10	6.099	0.751	2.259	1.183	1.001	0.707	0.646	0.470	3.129	29.657	20.694	35.535
11	6.586	0.739	2.594	1.337	0.520	1.087	0.162	0.085	1.739	31.879	24.953	33.358

APPENDIX E: Data of Khwopa Yatayat

S. N	Delay at Bus Stop			Delay at Intersection		Dar	Delay at Mid-Block			Average Total Travel Time	Mean Travel Time	95% Travel Time
	Expected Delay at Bus Stop	Dbs	Ducs	Expected Delay at Intersection	Di		Dpc	Dut)	Df			
	Min	Min	Min	Min	Min	Min	Min	Min	Min	Min	Min	Min
1	4.7430	0.4856	1.7083	0.6193	0.8954	0.2561	0.1185	0.2208	1.0980	25.9762	21.1935	27.8400
2	5.1227	0.5185	1.6554	0.4152	0.3819	0.4724	0.3211	0.2346	1.0263	26.7262	22.1160	28.3350
3	5.9579	0.6749	1.7596	1.2056	1.2184	0.5561	0.2721	0.1006	0.7617	28.7619	23.4185	32.2433
4	4.7895	0.4130	1.6577	1.0065	0.7459	0.2540	0.0799	0.1169	2.9367	27.6524	21.4482	34.6750
5	4.5556	0.2478	1.3037	0.2830	2.0204	0.1610	0.0000	0.0312	2.2466	29.4867	23.4760	31.5000
6	4.8604	0.4133	1.9280	0.3509	1.3460	0.9414	0.3291	0.1690	1.8089	29.3571	22.4215	39.0000
7	4.8531	0.6133	2.7738	0.9038	1.2467	0.3733	0.2076	0.2433	3.0528	33.1967	24.6857	38.5233
8	5.0401	0.7068	1.1168	1.5108	0.0000	0.2572	0.0768	0.1356	1.0059	25.7500	22.4510	26.8767
9	6.7210	0.6456	2.1403	0.3174	0.5572	0.2524	0.2593	0.0476	1.3723	27.5476	22.2728	33.1167
10	5.4905	0.7004	2.0002	0.2825	1.7709	0.3269	0.1504	0.0748	0.7776	29.1190	23.3178	35.4833

APPENDIX F: Data for Model Development

S.N.	D_{bs}	D_{ucs}	D_i	D_{ar}	D_{pc}	D_{ut}	D_f	MTT	PT
1	1.014	1.970	0.670	0.794	0.087	0.056	0.967	23.632	27.044
2	0.553	2.124	0.620	1.211	0.084	0.058	0.267	24.121	29.033
3	0.853	1.791	1.580	0.865	0.268	0.163	1.976	22.620	33.385
4	0.012	2.143	1.048	0.115	0.146	0.263	1.704	22.618	30.917
5	0.567	2.217	0.459	1.227	0.351	0.083	2.224	27.347	39.317
6	0.987	3.561	1.249	0.777	0.265	0.074	1.083	21.749	33.063
7	0.400	2.341	1.260	0.550	0.325	0.515	3.512	26.106	38.266
8	0.312	2.340	2.618	0.441	0.235	0.283	1.968	22.437	40.563
9	0.439	2.412	2.140	0.459	0.283	0.169	2.524	23.616	35.687
10	0.755	1.987	0.464	1.586	0.470	0.124	2.490	22.393	36.803
11	0.313	2.747	1.024	0.584	0.182	0.215	1.802	24.393	36.530
12	0.000	2.372	0.365	0.328	0.147	0.058	2.138	24.830	32.420
13	0.274	1.862	0.998	0.470	0.211	0.257	1.667	26.704	41.133
14	0.146	1.779	0.537	0.948	0.161	0.169	2.221	21.704	31.383
15	0.699	1.694	0.372	1.190	0.195	0.056	1.419	25.993	35.930
16	1.098	2.542	2.024	0.250	0.120	0.496	1.319	29.701	44.605
17	1.802	2.970	3.015	1.114	0.193	0.272	2.396	20.839	45.303
18	0.286	2.848	0.612	0.364	0.079	0.203	1.541	25.538	36.110
19	0.368	2.311	1.085	0.435	0.245	0.107	2.769	26.848	37.917
20	0.109	3.023	1.043	1.018	0.282	0.214	2.581	23.830	37.863

21	0.513	1.826	1.122	0.528	0.232	0.111	1.792	22.134	32.175
22	1.049	2.569	0.743	0.242	0.143	0.072	0.106	21.254	30.367
23	0.893	2.187	2.578	0.503	0.224	0.313	2.468	26.251	41.562
24	0.139	2.562	3.408	1.098	0.000	0.214	0.080	11.435	29.486
25	0.384	2.181	2.753	0.646	0.233	0.123	1.636	26.858	37.145
26	0.556	2.056	1.576	1.100	0.241	0.136	2.594	24.944	44.780
27	2.639	1.571	0.802	1.001	0.040	0.172	2.659	30.238	47.527
28	0.892	2.327	0.789	0.372	0.102	0.124	4.100	24.121	37.808
29	1.628	2.257	0.460	0.637	0.371	0.668	1.983	25.913	41.127
30	0.751	2.259	1.001	0.707	0.646	0.470	3.129	20.694	35.535
31	0.739	2.594	0.520	1.087	0.162	0.085	1.739	24.953	33.358
32	0.486	1.708	0.895	0.256	0.119	0.221	1.098	21.193	27.840
33	0.519	1.655	0.382	0.472	0.321	0.023	1.026	22.116	28.335
34	0.675	1.760	1.218	0.556	0.272	0.101	0.762	23.418	32.243
35	0.413	1.658	0.746	0.254	0.080	0.117	2.937	21.448	34.675
36	0.248	1.304	2.020	0.161	0.000	0.024	2.247	23.476	31.500
37	0.413	1.928	1.346	0.941	0.329	0.169	1.809	22.422	39.000
38	0.613	2.774	1.247	0.373	0.208	0.243	3.053	24.686	38.523
39	0.707	1.117	0.000	0.257	0.077	0.136	1.006	22.451	26.877
40	0.646	2.140	0.557	0.252	0.259	0.048	1.372	22.273	33.117
41	0.700	2.000	1.771	0.327	0.150	0.075	0.778	23.318	35.483

APPENDIX G: Data for Model Validation

S.N.	Delay due to Bus Stop			Delay at Intersection		D_{ar}	Unexpected Delay at Mid-Block			Average Total Travel Time	Mean Travel Time (MTT)	95 % Travel Time
	Expected Delay at Bus Stop	D_{bs}	D_{ucs}	Expected Delay at Intersection	D_{i}		D_{pc}	D_{ut}	D_{f})			
	Min	Min	Min	Min	Min	Min	Min	Min	Min	Min	Min	Min
1	7.063	0.891	2.178	0.322	1.095	0.445	0.094	0.249	0.177	27.767	22.638	29.358
2	8.811	2.909	1.689	0.141	1.987	0.337	0.067	0.221	0.199	27.950	14.672	31.558
3	8.072	2.326	1.492	5.694	1.210	0.639	0.238	0.063	0.298	29.802	23.537	34.892
4	9.736	3.606	1.743	1.119	1.347	0.685	0.115	0.123	0.326	31.443	16.784	35.533
5	7.055	1.005	2.774	0.136	0.938	0.507	0.035	0.163	0.293	27.814	22.099	30.293
6	7.730	1.546	2.624	0.300	1.205	0.252	0.111	0.218	0.254	31.633	25.423	41.933
7	9.259	3.094	2.334	0.672	1.587	0.225	0.043	0.166	0.499	31.621	23.674	35.408
8	7.644	1.982	2.081	0.027	1.361	1.018	0.107	0.228	0.360	26.807	19.670	30.150
9	8.902	2.160	2.514	0.443	1.794	0.214	0.022	0.176	5.723	29.992	14.905	31.707