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Public Route Assessment and Optimization of Bus Stop: A Case Study of Tarakeshwor

by

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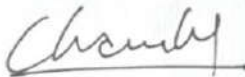
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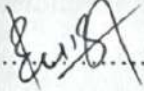
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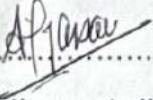
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ABSTRACT

Public transport systems in rapidly urbanizing municipalities of the Kathmandu Valley often operate without properly planned bus stop locations, resulting in irregular stopping patterns, redundancy, and poor accessibility. Tarakeshwor Municipality exhibits similar challenges due to informal stopping practices and lack of structured planning. This study aims to assess and optimize bus stop locations using a GIS-based approach integrated with network analysis, clustering, location–allocation modelling and followed by boarding alighting analysis. Primary data were collected through boarding–alighting surveys, route tracking, and field observations, while secondary spatial data such as road networks and satellite imagery were used to develop a geospatial database. Approximately 1,000 observed stopping points were refined into 140 candidate locations using K-means clustering. A network-based location–allocation model with a 400 m walking threshold was then applied for different demand categories, including built-up areas, schools, health facilities, and government offices. A demand-based weighting approach was used to integrate these results and derive a final set of 53 optimized bus stops.

The optimized configuration improves accessibility and serves the majority of demand points within the defined walking distance, although some peripheral areas remain underserved. Boarding–alighting analysis confirmed the operational feasibility of the optimized stops, with an average dwell time of 31.5 seconds during peak hours. Capacity assessment showed that most stops can accommodate peak bus demand with a single berth, except Lambagar, which requires additional infrastructure or splitting of stops.

Overall, the study demonstrates that GIS-based optimization combined with demand and operational analysis provides a practical framework for improving bus stops planning and efficiency in rapidly growing urban areas.

Keywords: GIS, Bus Stop Optimization, Location–Allocation, Boarding–Alighting, Dwell Time, Public Transport

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LIST OF ABBREVIATIONS

ADB	Asian Development Bank
B/A	Boarding/Alighting
CBS	Central Bureau of Statistics
DoTM	Department of Transport Management
GIS	Geographic Information System
GPS	Global Positioning System
JICA	Japan International Cooperation Agency
KVDA	Kathmandu Valley Development Authority
MoPIT	Ministry of Physical Infrastructure and Transport
MoUD	Ministry of Urban Development
MTMP	Municipal Transport Master Plan
O/D	Origin/Destination
OSM	OpenStreetMap
RNAC	Ratna Park Bus Terminal
SSE	Sum of Squared Errors
SRN	Strategic Road Network
UTM	Universal Transverse Mercator

CHAPTER 1. INTRODUCTION

1.1 Background

As urban areas expand and population densities increase, the need for reliable, accessible, and efficient mobility becomes even more critical. Among various transport modes, public transportation plays a central role, as it can move large numbers of passengers efficiently while reducing congestion and environmental impact (Giuffrida, Binetti, Viscio, & Ottomanelli, 2022). Cities and metropolitan regions function as hubs of economic, social, and cultural activity, requiring transportation systems that can efficiently move people and goods (Vuchic, 2007). Thus, the development and continuous improvement of public transport systems is considered a fundamental pillar of sustainable urban development.

Proper arrangements for urban bus transportation will increase the demand for public transport and the quality of urban life by reducing the rate of private vehicle use. The intensity of the use of private vehicles on the road is seen as the most important cause of traffic congestion and air pollution in many cities (N. Uludag, 2010). In rapidly urbanizing regions, public transport systems must evolve to address changing travel patterns, emerging activity centres, and increasing mobility demands. Designing an effective public transport network begins with the identification of optimal routes that ensure strong connectivity between residential neighbourhoods, employment centres, schools, health facilities, commercial areas, and other urban nodes. As cities expand and peripheral settlements grow, route planning must balance accessibility, travel time, and operational cost, while also minimizing environmental impact (Giuffrida et al., 2022). Thus, public transport network design is not purely about operational efficiency it must also advance broader goals of equity, sustainability, and urban resilience.

Among these, network design is the most crucial stage, as it forms the foundation upon which the remaining planning processes depend. Effective network design focuses on determining the most meaningful and efficient set of routes, stop locations, and service patterns across the city's-built environment. Urban public transport planning is typically

organized into five core stages: Network design, Frequency setting, Timetable development, Bus scheduling, and Driver scheduling (Chew & Lee, 2011). This includes maximizing coverage, reducing unnecessary route overlaps, establishing appropriate stop spacing, and ensuring that the transit system aligns with actual passenger demand.

In Nepal, and particularly in the Kathmandu Valley, the public transport system faces significant challenges. The current network is largely unstructured, with multiple operators running overlapping routes, poorly coordinated schedules, inconsistent service frequencies, irregular stop spacing, and limited coverage in peripheral settlements. These deficiencies reduce passenger convenience, increase walking distances, and contribute to road congestion as buses compete for passengers on the same corridor. Within Tarakeshwor Municipality; one of the emerging urban zones of Kathmandu; these challenges are even more pronounced due to fragmented settlement patterns, inadequate route planning, and lack of integration with municipal mobility needs.

1.2 Statement of Problem

Despite its rapid urbanization and increasing mobility demands, Tarakeshwor Municipality lacks a systematically planned public transport network, resulting in multiple operational and accessibility challenges. The existing routes have evolved organically rather than through structured planning, leading to route overlaps, redundancies, and inefficient resource utilization, which ultimately increase operational burden and passenger travel time. Such issues are commonly observed in uncoordinated public transport systems, where the absence of formal network design results in inefficient service patterns (Vuchic, 2007; Chew & Lee, 2011).

The absence of designated and standardized bus stop locations has resulted in inconsistent stop patterns throughout the municipality. Vehicles frequently stop at random or unsafe locations, contributing to delays, unpredictable travel conditions, and heightened safety risks for four passengers particularly children, elderly individuals, and persons with disabilities. Research indicates that poorly placed or irregular transit stops significantly reduce operational efficiency and compromise user comfort and safety (Delmelle & Casas, 2012; Hidalgo & Huizenga, 2013). Poorly planned routes and irregular stops further causes traffic congestion, especially along narrow or high-demand

corridors. Such inefficiencies contribute to longer travel times, reduced service reliability, and increased vehicular emissions challenges that mirror broader urban transport issues in growing South Asian cities (Huang et al., 2020).

Moreover, limited accessibility remains a substantial concern, as several residential clusters, institutional areas, and emerging commercial zones within Tarakeshwor Municipality remain properly underserved by existing public transport routes. Insufficient service coverage restricts resident's mobility, reduces access to employment and essential services, and hinders socio-economic development. Previous studies emphasize that equitable accessibility is a critical determinant of urban productivity and social inclusion (El-Geneidy & Levinson, 2006). These issues collectively reflect the urgent need to strategically restructure and expand the municipal transport network using data-driven approaches. Incorporating GIS-based network analysis, accessibility modelling, and optimization methods such as genetic algorithms can support the redesign of routes and the optimization of bus stop locations to enhance overall efficiency, service coverage, and passenger convenience. Addressing these challenges is essential for improving mobility, reducing congestion, enhancing safety, and ensuring that Tarakeshwor's growing population is served by a sustainable and well-integrated public transportation system.

1.3 Research Objective

The major objective of this study is to optimizations of stops and their assessment in Tarakeshwor Municipality through GIS-based spatial analysis and optimization of bus stop locations. The specific objectives considered are:

1. To determine the optimal number and spatial distribution of bus stops to improve accessibility to major trip-generating points.
2. Analysis of bus stops based on the field scenario with the help of boarding alighting data.

1.4 Scope of Study

This study focuses on improving public transportation accessibility in Tarakeshwor Municipality through the application of GIS-based network analysis and spatial

optimization techniques. The study emphasizes the optimization of bus stop locations and the assessment of service coverage by integrating field-collected passenger demand data with network-based GIS modelling.

The scope of the study includes:

1. Evaluation of the existing public transportation system, including route configuration, stop distribution, and operational characteristics.
2. Collection and analysis of Boarding Alighting (BA) and Origin–Destination (OD) data to represent passenger demand and travel patterns.
3. GPS-based mapping and validation of existing public transport routes and bus stops.
4. Development of a road network dataset suitable for network analysis through topology correction and attribute enhancement.
5. Application of service area analysis to assess current accessibility levels based on standard walking distance thresholds.
6. Identification of underserved areas and accessibility gaps within the municipality.
7. Application of a GIS-based Location–Allocation model to determine optimal bus stop locations using network distance and demand distribution.
8. Comparison of accessibility conditions before and after optimization to evaluate improvements in service coverage and passenger convenience.

The study is limited to spatial accessibility and network efficiency at the municipal level. Operational aspects such as timetable optimization, fare structure, and fleet scheduling are beyond the scope of this research.

1.5 Significance of the Study

Public transportation in rapidly urbanizing municipalities of the Kathmandu Valley has largely developed without systematic planning, leading to inefficient route structures, overlapping of routes, irregular bus stop locations, and uneven passenger access. In this context, the present study is significant because it applies a structured GIS-based and data-oriented approach to evaluate existing accessibility conditions and identify more suitable bus stop locations. By integrating spatial analysis, network analysis, and location–allocation modelling, the study demonstrates how modern planning tools can be used to improve the organization and efficiency of local public transport systems.

The findings of this research are expected to support municipal authorities and transport planners in making informed decisions regarding bus stop placement and service improvement. Better stop spacing and location can reduce passenger walking distance, reduce travel time, improve access for residents, students, and daily commuters, and enhance the overall usability of public transport. In the long term, improved accessibility may encourage greater use of public transport, helping to reduce dependence on private vehicles, traffic congestion, and related environmental impacts. The study also provides a practical framework that can be applied in other growing municipalities of Nepal facing similar transport challenges.

1.6 Limitations of the Study

1. The analysis is limited to Tarakeshwor Municipality, while public transport routes interact with the broader Kathmandu Valley transport network.
2. Spatial datasets such as built up areas, road networks, and facility locations were obtained from open source platforms (OpenStreetMap and Overpass Turbo), which may contain positional inaccuracies and incomplete attributes.
3. Built up area centroids were used as proxies for population demand points, which assumes uniform demand generation across all built up areas and does not account for variations in population density and land use.
4. Route preference is not considered during the collection of Boarding alighting data.
5. Slope, terrain, and pedestrian impedance factors were not considered.

1.7 Organizations of Reports

This thesis is structured into five chapters to present the research in a clear, logical, and systematic manner.

Chapter 1: Introduction: It provides the background and context of the study, emphasizing the importance of improved public transportation planning in the study area. It outlines the research problem, objectives, scope, and significance of the study, and concludes with an overview of the thesis structure.

Chapter 2: Literature Review: Literature review examines relevant theoretical concepts and previous empirical studies related to public transportation systems, accessibility assessment, GIS based network analysis, and bus stop planning. This chapter reviews existing research on service area analysis, location–allocation models, and data driven approaches in transport planning, which together form the conceptual and methodological foundation of the study.

Chapter 3: Methodology: It describes the research design and analytical procedures adopted in the study. It details the data collection process, development of spatial and network databases, and the application of analytical techniques such as service area analysis and location–allocation modelling to assess and optimize bus stop accessibility.

Chapter 4: Results and Discussion: This presents and analyses the outcomes of the study. It includes an evaluation of the existing public transportation system, assessment of current accessibility conditions, optimization results, and a comparison between existing and proposed scenarios. The findings are interpreted and discussed in relation to the study objectives and relevant literature.

Chapter 5: Conclusion and Recommendations: This part summarizes the key findings of the research and presents the main conclusions drawn from the analysis. This chapter also provides practical recommendations for improving public transportation planning in the study area, discusses the limitations of the study, and suggests directions for future research.

CHAPTER 2. LITERATURE REVIEW

2.1. Background

Chapter 2 reviews existing literature relevant to public transportation planning, accessibility assessment, and spatial optimization techniques. The review begins with a general overview of public transport systems and modes, followed by discussions on urbanization, population growth, and rising mobility demand in the Kathmandu Valley. It then examines the importance of structured public transport systems for sustainable urban mobility, along with institutional and governance challenges affecting transport planning in Nepal. The chapter further explores the characteristics and deficiencies of public transport services in the Kathmandu Valley and highlights the growing role of data driven and GIS based approaches in transit planning. Finally, previous studies on bus stop accessibility analysis and location–allocation modelling are reviewed to identify key research gaps, which form the basis for the present study.

2.2. Public Transport and Urban Mobility

Public transport is a shared passenger service operating along fixed routes and schedules, accessible to the general public. It plays a fundamental role in urban mobility systems by enabling efficient movement of large numbers of people, reducing private vehicle dependency, and improving access to employment, education, and essential services (Vuchic, 2007). Beyond mobility, public transport contributes to environmental sustainability by lowering per capita energy consumption and greenhouse gas emissions compared to private automobile use, particularly when operating at higher occupancy levels (Litman, 2023). Cities with well-functioning transit systems consistently show lower congestion, better air quality, and more equitable access to urban opportunities, especially for low-income households, students, elderly individuals, and persons with disabilities

In developing countries, however, public transport systems frequently evolve without systematic planning, resulting in informal and fragmented service structures. Pucher et

al. (2005) documented how rapid urbanization in South Asian cities has consistently outpaced the growth of organized transit infrastructure, creating overcrowded, unreliable, and spatially uneven services. Badami and Haider (2007) found that Indian cities suffer from route overlapping driven by commercial competition rather than network-level planning, leading to service duplication on high-demand corridors and complete absence of service in newly developed areas. These patterns are directly observed in the Kathmandu Valley context and within Tarakeshwor Municipality specifically, where unregulated private operators have shaped the network without any systematic coverage planning.

Urban public transport planning is typically organized into five sequential stages: network design, frequency setting, timetable development, vehicle scheduling, and driver scheduling (Chew & Lee, 2011). Of these, network design which includes the determination of routes, stop locations, and service patterns is the foundational stage, as decisions made at this level constrain all subsequent planning. Errors in stop placement, for instance, propagate through the entire planning hierarchy: a stop positioned too far from residential demand reduces ridership, increases dwell time variability, and undermines schedule reliability. Getting the spatial structure of the network right is therefore not merely a technical exercise but a precondition for transit system performance.

2.3. Need for Structured Public Transport and Governance in Nepal

Well-planned public transport networks improve operational efficiency, reduce redundant resource deployment, and provide equitable access across the urban area (Cervero, 2013). In Nepal, the absence of structured planning has produced a transit system in the Kathmandu Valley characterized by informal route allocation, poor stop infrastructure, and fragmented institutional oversight. Urban transportation management in Nepal is distributed across multiple agencies with overlapping mandates the Ministry of Physical Infrastructure and Transport (MoPIT), the Ministry of Urban Development (MoUD), the Kathmandu Valley Development Authority (KVDA), the Department of Transport Management (DoTM), Traffic Police, and individual municipalities without a coordinating metropolitan transport authority (ADB, 2019; Thapa & Murayama, 2021). This institutional fragmentation has historically allowed private operators to expand

services based on commercial interest rather than network need, perpetuating route duplication and irregular stop patterns.

The legal framework governing transport in Nepal the Vehicle and Transport Management Act 1993 and its Rules 1998, supplemented by the National Transport Policy 2001 provides a foundational structure for route permitting and vehicle operation. However, the recent federal restructuring of government responsibilities has complicated enforcement, particularly at the municipal level. The Urban Area Public Transport Management Authority Act 2022 represents a more recent effort to establish coordinated urban transit governance, though it remains only partially operational.

In the Kathmandu Valley specifically, multiple studies related public transportation had been performed. The Public Transport Restructuring Project (MoPIT, 2014) identified approximately 200 active bus routes, a large proportion of which were found to be redundant or spatially overlapping. More recent figures from FCCPTA (2024) suggest around 132 active routes, and the Transport Office in Ekantakuna has identified approximately 72 bus and minibus routes alongside 15 microbus and tempo routes. These varying counts reflect the continued absence of a single authoritative network map itself a product of the same institutional fragmentation that governance reforms are beginning to address. Bajracharya and Nakarmi (2021) observed that this organic route growth, combined with a lack of designated stop infrastructure, has contributed to declining transit mode shares even as the valley's population has grown to 3.03 million (CBS, 2021) and is projected to reach 3.74 million by 2030 (JICA, 2017).

2.4. Bus Stop Spacing, Walking Distance, and Accessibility Standards

Bus stop spacing is one of the most critical decisions in transit network design because it simultaneously affects accessibility and operational performance, and these two objectives pull in opposite directions. Closely spaced stops reduce the walking distance that passengers must cover to reach a service, improving access particularly for elderly, disabled, and mobility-constrained users. However, frequent stops increase dwell time accumulation along the route, raise running times, and reduce service reliability. Widely spaced stops do the opposite—they speed up services but impose longer walks that discourage use of public vehicles, especially for trips made on foot in warm weather or

with heavy loads. Finding the spacing that best balances these trade-offs is therefore a central problem in stop planning (Vuchic, 2007).

Research on acceptable walking distances to transit stops has converged on a broadly consistent international standard. Farewell and Marx (1996) suggest that 400 metres represents the practical ceiling of acceptable walking distance for the majority of transit users, beyond which ridership falls sharply as the discomfort of access outweighs the convenience of the service. El-Geneidy et al. (2014) examined observed walking distances across large transit systems and found that actual walking distances cluster between 400 and 500 metres along the road network consistent with the Farewell and Marx threshold and confirming that this figure is not merely a planning convention but reflects genuine behaviour. Studies suggest that optimal stop spacing typically falls in the range of 300 to 500 metres in urban areas (Furth & Rahbee, 2000). In the Kathmandu Valley context, Poudel (2025) found that passengers are generally willing to walk approximately 300 metres to access a bus stop, a somewhat shorter figure than international averages, likely reflecting the walkable character of peri-urban settlements and the high dependence on transit for daily mobility.

The present study adopts a 400-metre walking threshold as its accessibility standard, consistent with the international evidence and slightly more conservative than the local preference, to ensure that proposed stop locations serve the broadest possible range of users. Delmelle et al. (2012) used spatial analysis to show that stops located within very short distances of each other a common outcome of informal stop development provide negligible additional coverage while degrading operational performance. Their framework for identifying stop redundancy through catchment area overlap analysis directly informs the approach taken in this study for evaluating Tarakeshwor's existing informal stop pattern. Giuffrida et al. (2022) further proposed that equity-based transit assessment frameworks should treat walking distance to stops as a primary performance indicator, arguing that accessibility to bus stops is a matter of social equity as much as operational efficiency, since all residential areas deserve to fall within a reasonable walking catchment of transit service.

2.5. GIS-based Accessibility Analysis and Bus Stop Planning

Geographic Information Systems have become essential tools in transportation planning for evaluating the spatial coverage and performance of transit networks. GIS allows the integration of road networks, demand locations, and stop positions into a unified analytical environment, enabling planners to assess service coverage and accessibility in technical and systematic way. In bus stop accessibility studies, network-based service area analysis is the standard approach: it delineates the set of road network locations reachable from a stop within a specified walking distance, producing a realistic representation of the stop's catchment area that accounts for the actual structure of the street network. Delmelle et al. (2012) demonstrated that network-based catchment areas are often substantially smaller than Euclidean buffers on the same network, particularly in areas with limited pedestrian crossing opportunities or indirect paths, meaning that Euclidean approaches systematically overestimate transit accessibility.

El-Geneidy et al. (2014) applied GIS network analysis at scale to examine walking distances and found that stop redundancy multiple stops serving essentially the same spatial catchment was widespread in the systems they studied. Corazza and Favaretto (2019) used GIS-based accessibility assessment in an Italian urban context to identify coverage gaps that were invisible to qualitative inspection, demonstrating that systematic spatial analysis adds genuine planning value beyond expert judgment. Shatnawi et al. (2020) combined GIS with optimization techniques to determine optimal bus stop locations in a developing-country context, confirming that integrated spatial approaches work effectively even in data-scarce environments. These studies collectively demonstrate that GIS-based accessibility analysis is not merely a visualization tool but a genuine decision-support framework capable of producing actionable planning recommendations.

In this present study, the road network of Tarakeshwor Municipality was digitized and topology-corrected in ArcGIS 10.8 to create a network dataset for network analysis. Walking distance was used as the network impedance parameter, consistent with access patterns in peri-urban Nepal where pedestrian access to bus stops is the dominant mode of transit access. Service areas of 400 metres were computed from each candidate stop location, and the resulting coverage polygons were evaluated against the spatial distribution of demand points across the municipality's four demand categories: built-up residential areas, schools, government offices, and health facilities.

2.6. Spatial Clustering for Transit Stop Candidate Generation

When public transport systems develop organically, a large number of informal stopping locations accumulate along popular corridors, many of them clustered within metres of each other and serving essentially the same demand. Before spatial optimization can be meaningfully applied, these raw observed locations must be consolidated into a representative set of candidate stops that captures the spatial structure of passenger activity without retaining every redundant point. Spatial clustering is the standard methodological tool for this pre-processing task in transit planning (Ibarra-Rojas et al., 2015).

K-means clustering is one of the most widely applied algorithms for this purpose. The method partitions a set of geographic points into k clusters by iteratively assigning each point to its nearest cluster centroid and updating centroids until the total within-cluster sum of squared errors (SSE) is minimized. The key challenge in applying K-means to transit stop data is the selection of k , which is not known in advance and must be estimated from the data. The elbow method addresses this by plotting SSE against increasing values of k and identifying the inflection point the "elbow" at which additional clusters produce diminishing reductions in SSE. This inflection point represents the value of k that best balances simplicity with high accuracy to the spatial structure of the data. Fan and Machemehl (2006) applied clustering-based pre-processing in transit optimization and showed that the quality of the candidate facility set directly determines the quality of downstream optimization outputs. Farahani et al. (2013) noted that pre-processing through clustering also reduces the combinatorial complexity of subsequent location-allocation problems, making them computationally tractable for standard GIS software.

In the present study, approximately 1,000 boarding-alighting points recorded across eleven routes in Tarakeshwor Municipality were subjected to K-means clustering. The elbow method applied to the SSE plot identified 140 as the optimal cluster count, yielding 140 representative candidate bus stop locations that were carried forward into the location-allocation analysis. This approach ensured that the candidate set was grounded in observed passenger activity reflecting where buses actually stop and people actually board and alight rather than being derived from arbitrary grid points or administrative boundaries.

2.7. Location–Allocation Modelling for Optimal Stop Placement

Location–allocation models are operations research tools that simultaneously determine the best locations for a set of facilities and the assignment of spatially distributed demand to those facilities, with the objective of minimizing aggregate travel distance or maximizing coverage within a specified service threshold. In public transport planning, they are the standard optimization framework for transit stop placement problems (Esri-ArcMap). The foundational model types are the P-median formulation, which minimizes total weighted travel distance between demand points and their nearest assigned stop, and the maximal coverage location problem, which maximizes the number of demand points served within a defined distance threshold given a fixed number of stops to place (Church & ReVelle, 1974; ReVelle & Swain, 1970).

Murray (2003) applied the maximal coverage model directly to transit stop accessibility and showed that model-derived stop placements consistently outperform historically evolved configurations in terms of the proportion of demand brought within the walking accessibility threshold. His findings established the maximal coverage formulation as the most appropriate model type when the planning objective is to extend service coverage to the maximum possible share of the population which is precisely the objective in rapidly urbanizing municipalities where coverage gaps rather than excess density are the primary problem. Shatnawi et al. (2020) further demonstrated that combining location–allocation models with GIS network distance data rather than Euclidean approximations substantially improves the realism and policy relevance of the results. The set-covering model, a related formulation that identifies the minimum number of facilities needed to bring all demand points within the service threshold, provides a useful complementary check on model outputs. Similarly, as different activities generate different types and number of trips there is direct influence of land-use on travel demand. Different point of interest like residential areas, health- post, offices and schools have different activities and the trip generations depends on the activities in that places as they do not contribute equally to the passenger’s movements. So, treating all demand points with equal importance may reduce the practical relevance of stop optimization. Ahmed et al. (2020), in their study on trip generation rates of land uses in Dhaka, showed that trip generation varies considerably across land-use categories in a developing-country urban context. Their findings indicated that non-residential land uses, particularly healthcare,

educational, commercial, and office uses, generate higher travel demand than residential land uses.

In this study, three model types were applied across four demand categories in ArcGIS Network Analyst. The P-median model was used for built-up residential areas, where minimizing average walking distance across all residential demand is the primary objective. The maximal coverage model was applied to institutional demand schools, government offices, and health facilities where ensuring that the maximum number of facilities falls within the 400-metre threshold is the planning priority. The set-covering model served as a verification formulation. This multi-model approach, applied category by category, produces a richer and more defensible set of optimal stop locations than any single formulation would yield, since it matches the model objective function to the specific planning logic of each demand type.

2.8. Boarding–Alighting Surveys and Dwell Time in Transit Planning

In stops planning boarding–alighting surveys provide the most direct field-level information. By recording the number of passengers entering and exiting vehicles at each stop, these surveys reveal actual usage patterns that neither route-level ridership counts nor origin–destination data can capture at the stop scale. Vuchic (2007) recognized B/A surveys as a fundamental data collection method for transit systems, particularly in contexts where electronic passenger counting systems are unavailable. Beyond confirming which stops carry high demand, B/A data enable planners to distinguish active stops from nominal stops locations where vehicles formally pause but few or no passengers exchange supporting evidence-based decisions on stop consolidation and infrastructure prioritization.

Dwell time is the time a bus spends stationary at a stop during a passenger exchange. It is a critical operational parameter because it directly affects route running time, headway regularity, and schedule adherence. Longer dwell times at high-demand stops accumulate into significant travel time delays along a route and can disrupt headways when buses bunch behind each other at busy stops. The standard approach in transit planning literature models dwell time as a linear function of passenger activity: a fixed minimum time component accounting for door operation and vehicle deceleration and acceleration, plus a per-passenger coefficient reflecting average boarding and alighting

movement rates (Levinson, 1983; Kittelson & Associates, 2013). This formulation has been applied across a range of urban and peri-urban bus systems and provides a practical basis for estimating stop-level operational characteristics without requiring specialized sensor equipment.

Bus stop capacity - the maximum number of buses a stop can serve per hour follows directly from dwell time. As dwell time increases, the number of buses that can cycle through a single berth per hour decreases proportionally, since each vehicle occupies the berth for longer. Kittelson & Associates (2013) documented that stops where peak bus frequency exceeds single-berth capacity generate queuing, road-side stopping, and compounding delays that reduce reliability for all routes serving that corridor. Understanding berth capacity relative to peak demand is therefore essential for determining where additional infrastructure provision is needed. In the present study, dwell time was estimated from field-collected B/A data using the formula $D = 5 + 2.75 \times (B + A)$, where D is dwell time in seconds, B is boarding passengers, and A is alighting passengers. This field-derived data was then used to compute bus capacity per berth per hour at each of the 53 optimized stops, enabling identification of stops where operational constraints require physical infrastructure improvements.

2.9. Public Transport Challenges in Kathmandu Valley

Public transport services in the Kathmandu Valley have evolved through decades of unregulated private operator competition rather than systematic public planning. Many South Asian cities, including Kathmandu, lack a formal functional classification of routes, and services develop organically in response to commercial demand rather than network-level coverage logic (Tiwari, 2002; Pucher et al., 2007). The result is service duplication on high-demand corridors and complete absence of service in lower-density or newly developed areas (Badami & Haider, 2007). For peri-urban municipalities such as Tarakeshwor, which have absorbed significant residential growth through municipal expansion without a corresponding structured extension of transit services, this pattern creates particularly acute accessibility gaps.

A number of studies have documented the operational and spatial inefficiencies of Kathmandu's transit system. Shahi et al. (2018) examined travel time reliability on selected valley routes and found high variability attributable in part to informal and

unregulated stopping practices. Thapa et al. (2024) compared travel time reliability across different service providers on the Airport to Narayan Gopal Chowk corridor and found significant inconsistencies linked to stop management. Bhattarai and Shahi (2021) highlighted the need for multi-modal integration as a longer-term strategy, while Bajracharya and Nakarmi (2021) provided network-level evidence of route redundancy and coverage inefficiency. These diagnostic studies collectively establish the context within which the present research operates: the problems are well identified, but data-driven solutions at the municipal scale remain scarce.

Kathmandu Metropolitan City has recently begun digitizing bus stops under World Bank support, and the Urban Area Public Transport Management Authority Act 2022 signals a policy direction toward more structured governance. However, newly urbanized municipalities on the metropolitan fringe, including Tarakeshwor, have yet to benefit from these initiatives. This study is therefore timely in developing a replicable, GIS-based planning methodology that can be applied at the municipal level with locally available data and standard software.

2.10. Research Gap and Justification for the Present Study

Despite a growing body of literature identifying the structural deficiencies of Kathmandu's public transport system, very few studies propose actionable, data driven solutions for route classification and redesign, and almost none focus on the newly expanded municipalities such as Tarakeshwor. The present research addresses this critical gap by developing and applying a comprehensive data driven framework integrating passenger demand data, road geography, existing service patterns, and multi modal integration potential to classify and rationalize public transport routes in Tarakeshwor Municipality. This work builds on the diagnostic findings of Shahi et al. (2018), Bhattarai and Shahi (2021), and Bajracharya and Nakarmi (2021) while introducing a replicable methodological innovation suited to resource constrained South Asian cities.

CHAPTER 3. METHODOLOGY

3.1. Background

The overall research methodology adopted in this study is presented in the form of a flowchart, showing the sequential process from data collection to analysis and interpretation. The methodology integrates field-based data collection with GIS-based spatial and network analysis techniques to assess and optimize public transport accessibility in Tarakeshwor Municipality.

Both primary and secondary data were used in the study. Primary data were collected through boarding–alighting surveys, route tracking, field observations, and interviews with transport operators. These data helped identify actual stopping locations, passenger movement patterns, and operational characteristics of the existing public transport system. Secondary data, including road networks, administrative boundaries, population information, satellite imagery, and route-related records, were collected from municipal sources, published reports, and open-source spatial platforms.

The collected data were cleaned, standardized, and digitized using Google Maps, Google Earth, and ArcGIS. Observed boarding–alighting points were converted into spatial layers, and public transport routes were mapped using GPS-based route tracking. The road network was prepared for network analysis through topology correction, segmentation, and attribute assignment to ensure proper connectivity.

Major demand points representing trip-generating locations were also identified and digitized. These included built-up residential areas, schools, health facilities, and government offices. The observed stopping points were first refined using K-means clustering to reduce redundancy and generate representative candidate bus stop locations. Finally, the candidate stops, demand points, and road network were used as inputs in the ArcGIS Network Analyst Location–Allocation model. A walking distance threshold was applied as the network impedance to determine optimized bus stop locations that improve accessibility, reduce redundancy, and better serve major demand-generating areas.

3.2. Research methodology

The research methodology is illustrated in Figure 3.1. This study adopts a GIS based spatial analysis approach to evaluate and optimize bus stop accessibility within the selected study area.

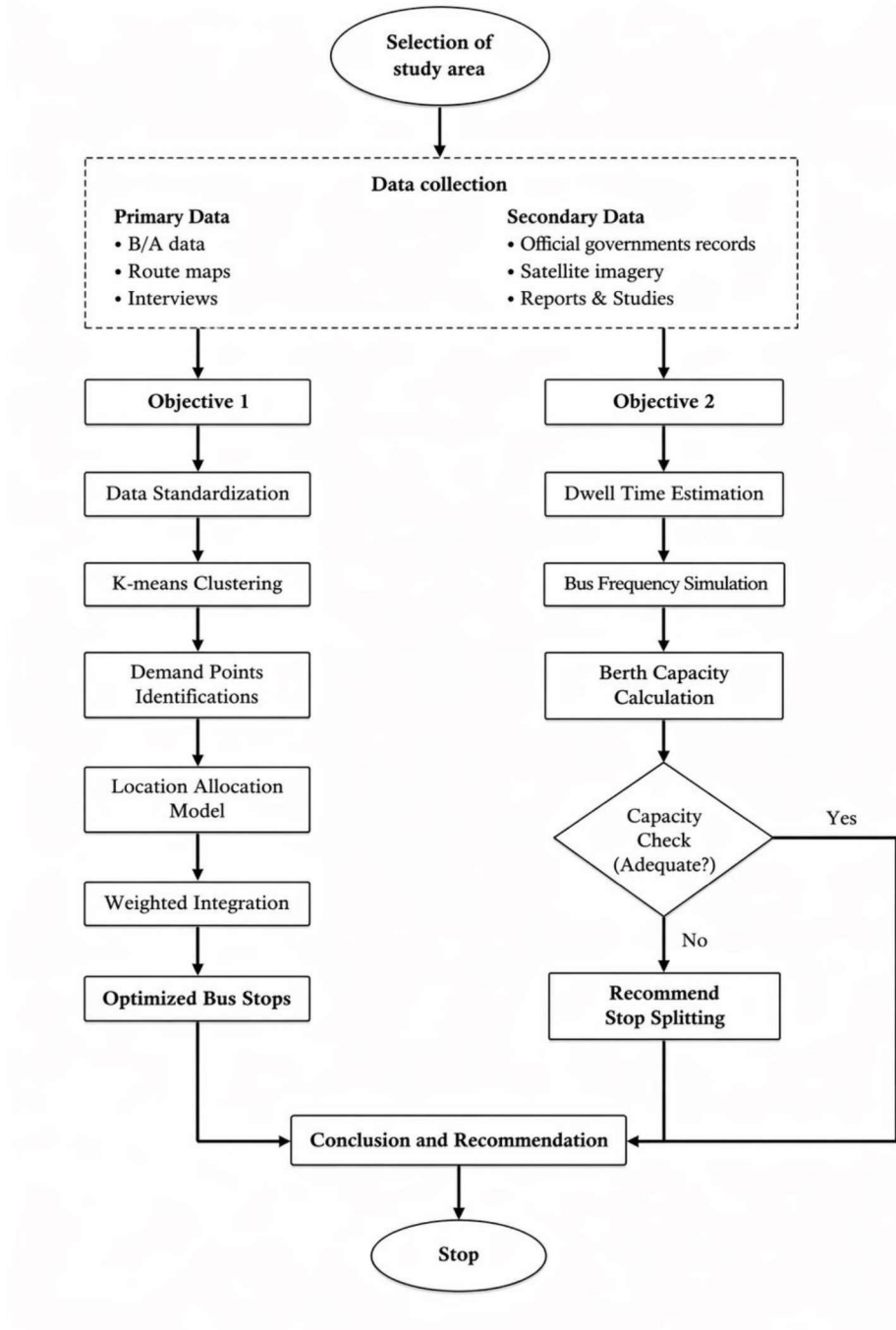


Figure 3.1 Research Design

The methodology integrates primary and secondary data sources, including boarding and alighting records, route maps, field observations, government records, satellite imagery, and relevant reports. These datasets were compiled to understand existing public transport conditions and identify spatial demand patterns. The collected data were standardized, cleaned, and digitized in a Geographic Information System (GIS) environment to create spatial layers representing bus routes, existing stops, and major demand points such as built up areas, schools, hospitals, and government offices.

Subsequently, exploratory spatial analysis and GIS network analysis were conducted to examine the accessibility of existing bus stops. Based on this analysis, a location-allocation model was applied to determine optimized bus stop locations that improve accessibility and service coverage. This methodology provides a systematic framework for assessing transit accessibility and identifying spatially efficient bus stop locations using GIS based analytical techniques.

3.3. Development of Objective Function

The objective functions were made based on the core goals of the study, which are to improve accessibility, and determine optimal bus stop locations that best serve passenger convenience and travel demand. To achieve this, a comprehensive review of relevant literature was conducted to identify and adapt the most effective and widely recognized objective functions used in transit network design and stop location allocation problems. The final objective function was a multiple point of interest formulation that explicitly integrates.

Service coverage: maximizing the proportion of the population and key facilities located within the standard walking distance (400–500 m) of bus stops. Farewell and Marx said that 400 meters is the maximum acceptable walking distance because people strongly prefer short walks to reach transit stops. Reducing walking time makes public transport more appealing and user friendly (Farewell & Marx, 1996).

Accessibility: minimizing overall travel impedance (e.g., combined walking time, waiting time, and in vehicle travel time) for the entire demand.

This carefully constructed objective function will guide the location allocation model and route optimization process, ensuring that the proposed network improvements are both equitable and efficient in meeting actual passenger needs.

3.4. Study Area

Tarakeshwor Municipality is located in the north western part of Kathmandu Valley and represents one of the rapidly urbanizing peri urban municipalities of the metropolitan region. The municipality consists of 11 administrative wards as shown in Figure 3.2 and accommodates an estimated population of approximately 152,000 residents. Its geographical proximity to the core areas of Kathmandu has accelerated urban expansion, land use transformation, and population growth over recent years. As a result, Tarakeshwor has experienced a substantial increase in daily travel demand associated with commuting for employment, education, healthcare, and administrative services.

Despite this growth, the public transportation system within the municipality remains largely informal and inadequately planned. Public vehicle services operate without a clearly structured route network or systematically planned bus stop locations, leading to irregular stop spacing, route overlaps, and inefficient service coverage. These conditions contribute to increased travel times, traffic congestion, and reduced accessibility, particularly for residents living in newly developed or peripheral areas of the municipality.

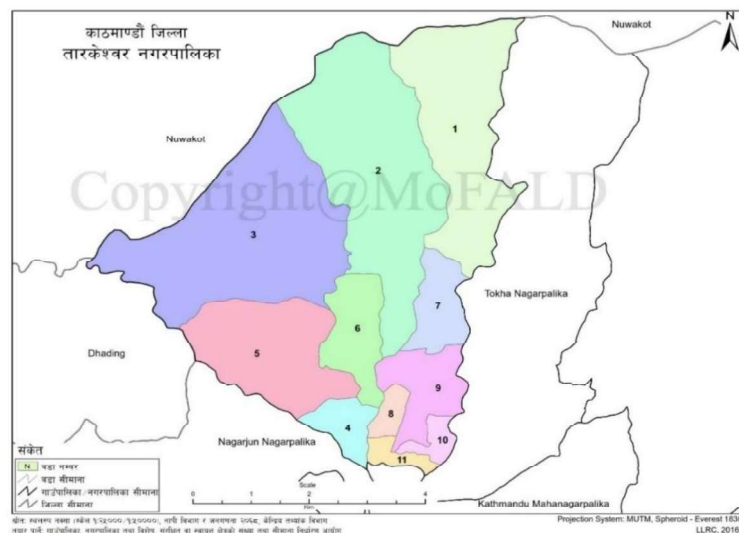


Figure 3.2: Study Area With Roads

The road network of Tarakeshwor Municipality comprises a mix of national SRN (Strategic Road Network) and local roads, many of which were not originally designed to accommodate the current level of traffic demand. Rapid urbanization, combined with increasing reliance on private vehicles due to limited public transport accessibility, has further intensified pressure on the existing road infrastructure. Consequently, improving the efficiency and spatial coverage of public transport has become a critical planning concern for the municipality.

3.5. Data Collection

To support the GIS based accessibility assessment and bus stop optimization, both primary and secondary data sources were used to develop a comprehensive and reliable dataset. The data collection process was designed to capture actual public transport operations, passenger demand patterns, and network characteristics within the study area.

3.5.1. Primary Data Collection

3.5.1.1. Boarding–Alighting (B/A) Survey

A structured boarding–alighting survey was conducted to capture passenger movement patterns and route level demand characteristics. Trained enumerators were positioned inside public buses and minibuses operating along all major public transport routes within all public bus service routes of Tarakeshwor Municipality as shown in the Figure 3.3 Passenger boarding and alighting counts were recorded at each observed stop location. Surveys were carried out during three representative time periods morning peak, off peak, and evening peak to account for temporal variations in ridership. Each route was surveyed in both travel directions to ensure balanced and comprehensive coverage. Boarding–alighting surveys are widely recognized as an effective method for understanding transit demand and stop level usage patterns (Vuchic, 2007). Sets of B/A data were collected by using the app named Eppicollect5. A project was created by setting the multiple open and close ended questions sets. Table 3-1 shows the list of routes in which B/A survey was conducted.

Table 3-1: Name of Road With Length

S.N	Route name	Length(km)
1	Gol Dhunga Machhapokhari RNAC	3.6
2	Lolang Machhapokhari RNAC	2.9
3	Paiyyatar Machhapokhari RNAC	3.8
4	Tinpiple Machhapokhari RNAC	6.7
5	Jitpur Fedi Machhapokhari RNAC	6.9
6	Kavresthali Machhapokhari Kalanki	6.2
7	Kavresthali Machhapokhari RNAC	7.2
8	Kavresthali Machhapokhari Teaching RNAC	8.2
9	Sangla Machhapokhari RNAC	7.9
10	Ranipauwa Machhapokhari RNAC	10.8
11	Manmaju Malpot Bishnumati corridor Gongabu RNAC	1.6

Length in the table is the only length with in the municipality. And the final boarding alighting sample data are presented in the annex.



Figure 3.3: All Public Transportation Service Providing Route

3.5.1.2. Route Tracking

Field based route tracking was conducted for all operating public transport routes to ensure spatial accuracy and data authenticity. Each route was tracked using GPS enabled mobile applications named Kobo collect during regular operational hours, covering both two-way directions. The recorded GPS tracks were later processed and digitized in a google earth and ArcGis10.8 to generate accurate route alignments for network analysis.

3.5.1.3. Structured Interviews

Structured interviews were conducted with public transport operators and passengers to obtain qualitative insights into operational conditions, service reliability, and user experiences. A standardized questionnaire comprising both open ended and close ended questions was used to ensure consistency and comparability across respondents. For vehicle operators, including drivers and helpers, questions focused on operational aspects such as service frequency, vehicle capacity, headway, and time intervals between consecutive trips at bus stops. No predefined questionnaire was used for the boarding–alighting survey, as this component involved direct observation and manual recording of passenger boarding and alighting activities at stop locations. The findings from the interviews complemented the quantitative data and supported the identification of practical issues related to bus stop locations, service coverage, and overall system performance.

3.5.1.4. Road Condition Inventory

A road condition inventory was carried out along major public transport corridors to assess physical and operational characteristics of the road network. This included documentation of road width, pavement condition, surface type, and the condition of existing bus stops, shelters and positions of working conditions stops. Existing bus stop conditions and the vehicle stops conditions were observed and the points having proper and good conditions bus stops were noted properly. In addition, the presence of traffic control devices, pedestrian crossings, and roadside safety features was recorded to understand their influence on stop accessibility and service quality of public transportation within the whole municipality.

3.5.2. Secondary Data Collection

Secondary data were collected to complement field observations and support spatial and network analysis. Official government records from the Department of Transport Management (DoTM) and Tarakeshwor Municipality were used to obtain information on registered routes, route permits, and administrative boundaries. Population data and ward level statistics were obtained from national census records and municipal sources.

Satellite imagery and open source spatial datasets, particularly OpenStreetMap (OSM), Open turbo were used for road network development, verification of route alignments, and identification of existing bus stop locations. In addition, published reports and previous studies related to public transportation and urban mobility in the Kathmandu Valley were reviewed to provide contextual understanding and support methodological decisions. Where available, relevant municipal transport planning documents, including the Municipal Transport Master Plan (MTMP), were studied.

3.5.2.1. Data Attributes

The collected data covered key attributes required for accessibility and optimization analysis, including route length, stop spacing, stop locations, boarding–alighting volumes, travel time per trip, daily ridership, fleet size per route, service frequency and headway, and operational hours. These attributes formed the basis for GIS based service area analysis and location–allocation modelling.

3.5.2.2. Public Transport Routes and Operator Survey Data

Data on public transport routes and operational characteristics were collected through surveys conducted at the offices of service providers operating within Tarakeshwor Municipality. The survey indicates that Tarakeshwor Yatayat Pvt. Ltd. is the dominant public transport operator in the study area, providing services on 11 major routes with a fleet of more than 150 vehicles in daily operation. These routes connect the municipality with key destinations such as Machhapokhari, Gongabu, Kalanki, and RNAC, reflecting high commuter demand.

In addition, Samakhusi Yatayat and Maulik Yatayat also provide regular services within the municipality. Samakhusi Yatayat operates a slightly larger fleet than Maulik Yatayat and offers more frequent services along several corridors, indicating its growing role in meeting daily travel demand. Maulik Yatayat operates a comparatively smaller number

of vehicles but contributes to service coverage along selected routes. Super Yatayat is a relatively new operator, currently operating lesser than five vehicles on a limited route within the municipality. Although its present contribution is minimal, planned fleet expansion suggests potential future growth.

Overall, the operator survey reveals that public transport services in Tarakeshwor Municipality are characterized by a small number of dominant private operators with overlapping routes and varying service frequencies. This operational pattern highlights the need for systematic route evaluation and optimized bus stop planning, which is addressed through the GIS based analysis in this study.

Following is the details of different service providers with in Tarakeshwor municipality. These all are the data provided by different service providers with in the Tarakeshwor municipality.

Tarakeshwor Yatayat Pvt. Ltd.

Total Vehicle: 170

Daily Operation: 160+

Types	No of seats
Micro bus	16
Mini bus	33
T K	29
Others	31

Other Information:

Table 3-2: Routes Where Tarakeshwor Yatayat Provide Their Services

Route	Bus	No. of Vehicles	Avg no. of trips (single veh)	Total Trips	Remarks
Dhagurne Pani Machhapokhari RNAC	Micro Bus	17	7	119	
Gol Dhunga Machhapokhari RNAC	Other	14	5	70	
Lolang Machhapokhari RNAC	Other	17	5	85	
Paiyyatar Machhapokhari RNAC	Other	12	5	60	
Tinpiple Machhapokhari RNAC	Other	18	4	72	

Jitpur Fedi Machhapokhari RNAC	Other	16	4	64	
Kavresthali Machhapokhari Kalanki	Other	11			Avg. not available
Kavresthali Machhapokhari RNAC	Mini Bus	13			Avg. not available
Kavresthali Machhapokhari Teaching RNAC	TK	9			Avg. not available
Sangla Machhapokhari RNAC	Other	24	4	96	
Ranipauwa Machhapokhari RNAC	Other	16	1 2	24	

Maulik Yatayat Pvt. Ltd.

Total Vehicle: 22

Daily Operation: 19+

Types	No of seats
bus	35
Mini bus	33
T K	27
Others	31

Other Informations:

Table 3-3: Routes Where Maulik Yatayat Provide Their Services

Route	Bus	No. of Vehicles	Avg no. of trips (single veh)	Total Trips	Remarks
Kavresthali Machhapokhari Teaching RNAC	Others	13	4	52	
Jitpur Fedi Machhapokhari RNAC	Other	4	4	16	
Tinpipla Machhapokhari RNAC	Bus	2	5	10	

Super Yatayat Pvt. Ltd.

Total Vehicles: 3

New Vehicles coming soon: 8 (in next month)

Types	No of seats
Others	31

Other Informations:

Table 3-4: Routes Where Super Yatayat Provide Their Services

Route	Bus	No. of Vehicles	Avg no. of trips (single veh)	Total Trips	Remarks
Jarankhu Machhapokhari Teaching RNAC	Others	3	4	52	

Samakhusi Yatayat Pvt. Ltd.

Total Vehicle: 59

New Vehicles coming soon: 5

Table 3-5: Routes Where Samakhusi Yatayat Provide Their Services

Route	Bus	No. of Vehicles	Avg no. of trips (single veh)	Total Trips	Remarks
Nagpokhari Ganesthan Gongabu RNAC	Microbus	12	5	60	
Sangla Bhatkekopul Ganeshsthan Gongabu	Microbus	12	5	60	
Manmajju Malpot Bishnumati corridor Gongabu RNAC	TK	10	4	40	
Bhatkekopul Bishnumati Corridor Buspark Gongabu_ RNAC	Mini Bus	10	4	40	

3.6. Existing Vehicle Stop Pattern

The existing public transport stop pattern within Tarakeshwor Municipality is largely unstructured and informal. At present, there are no clearly designated or physically marked bus stops across most parts of the municipality. Public vehicles frequently stop at arbitrary locations along the roadway based on passenger demand, driver discretion, or convenience rather than predefined stopping points. This practice results in a highly irregular stop pattern and reflects the absence of systematic bus stop planning within the municipal transport system.

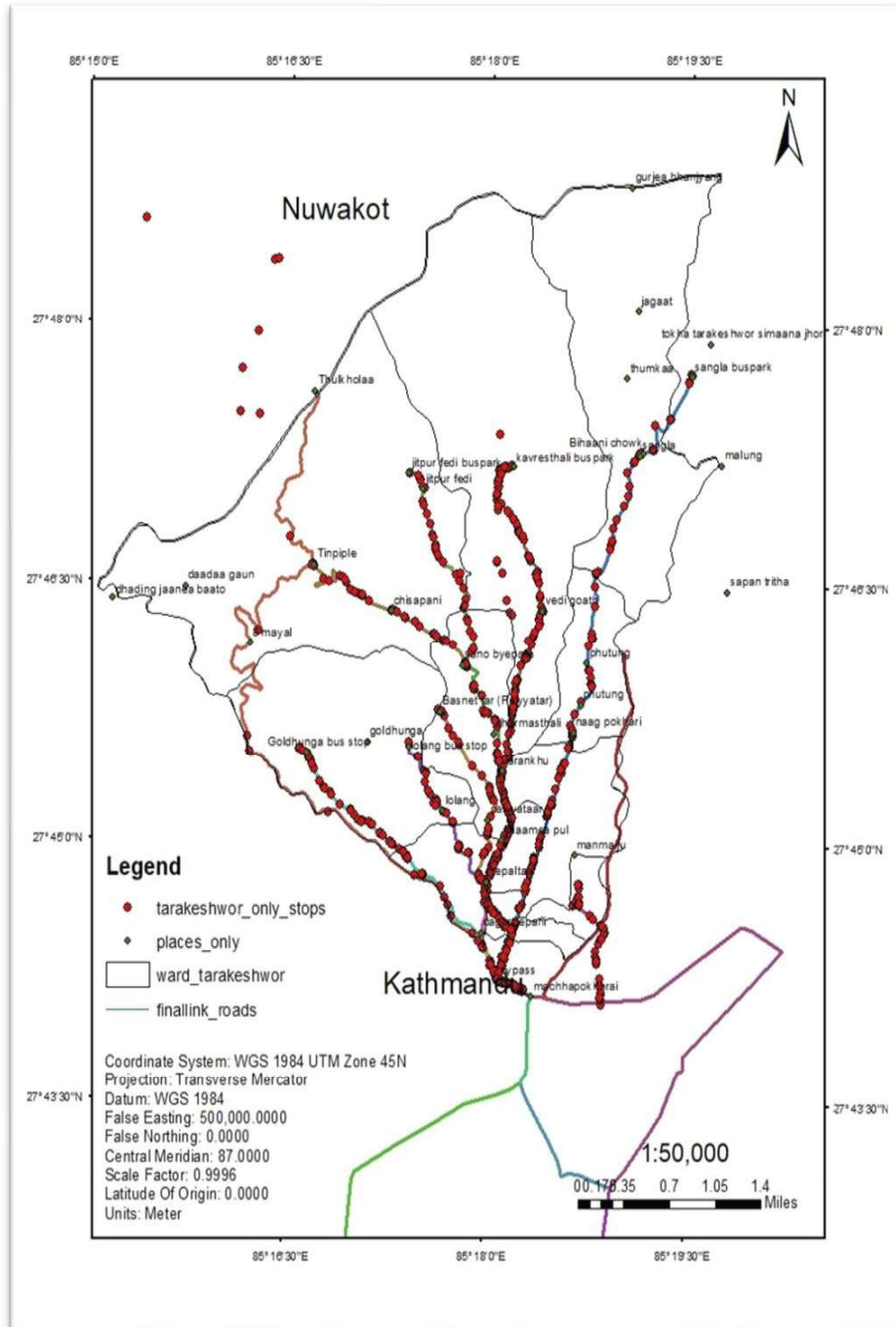


Figure 3.4: Existing Stop Pattern

Field observations and boarding–alighting surveys indicate that vehicles often stop mostly at curb sides, sharp curves, narrow road segments, and areas without adequate pedestrian space. Such random stopping behaviour poses safety risks to both passengers and other road users, disrupts traffic flow, and contributes to localized congestion,

particularly along busy corridors. The lack of standardized stop spacing and physical infrastructure further reduces operational efficiency and increases travel time variability.

During the field survey, boarding–alighting data were collected from approximately 1,000 observed stopping locations as shown in the Figure 3.4 across three distinct time periods: morning peak, daytime off peak, and evening peak hours. The large number of observed stopping points highlights the extent of stop dispersion and redundancy within the existing system. Analysis of the collected data shows that stop frequency is notably higher in densely populated and mixed-use areas, where vehicles tend to stop at very short intervals to respond to concentrated passenger demand.

Conversely, in lower density or peripheral areas, stops are more widely spaced and less consistently used, resulting in uneven accessibility across the municipality. This spatial imbalance in stop distribution indicates that current stop locations are demand driven but not optimized from a network efficiency or safety perspective. Overall, the observed vehicle stop pattern demonstrates a strong need for rationalization and optimization of bus stop locations based on accessibility, demand distribution, and network characteristics. These findings provide a critical basis for applying GIS based service area analysis and location–allocation modelling in the subsequent stages of this study to propose a more structured, safe, and efficient bus stop system.

3.7. K means Clustering

Clustering analysis is an unsupervised machine learning technique used to group spatial observations based on similarity measures. Among various clustering methods such as hierarchical clustering and density based clustering (DBSCAN), K means clustering is widely used due to its computational efficiency and suitability for geographical datasets and transportation stops clustering.

In this study, K means clustering was applied to refine approximately 1,000 observed boarding–alighting stops locations into a reduced and representative set of feasible bus stop locations. Since many of the observed stopping points were spatially close and redundant, clustering was necessary to consolidate these into optimal centroid based stop locations. K means partitions a dataset into K clusters by minimizing within cluster

variance. Each data point is assigned to the nearest centroid using the Euclidean distance metric. The Euclidean distance between a data point x_i and centroid C_j is expressed as:

$$d(x_i, c_j) = \sqrt{\sum_{k=1}^n (x_{ik} - c_{jk})^2} \dots\dots\dots(3.1)$$

Where

$d(x_i, C_j)$ = Euclidean distance between data point x_i and centroid C_j

$x_i = (x_{i1}, X_{i2}, \dots, x_{in})$ = coordinate of data point i

$C_j = (C_{j1}, C_{j2}, \dots, C_{jn})$ = coordinate of centroid j

x_{ik} = value of the k th feature of data point i

C_{jk} = value of the k th feature of centroid j

n = number of spatial dimensions

3.8. Elbow Method

Selecting the appropriate number of clusters (K) is a critical step in clustering analysis. In this research, the Elbow Method was applied to determine the optimal number of clusters.

$$SSE = \sum_{j=1}^k \sum_{x_i \in C_j} \|x_i - C_j\|^2 \dots\dots\dots(3.2)$$

Where:

SSE = Sum of Square Errors (inertia)

K = Number of clusters

X_i = data point

C_j = centroid of cluster j

The elbow method evaluates SSE for increasing values of K . Initially, $K = 1$ is assumed, and SSE is computed. K is then incremented iteratively, and SSE is calculated for each iteration. As K increases, SSE decreases because clusters become smaller and more compact. However, after a certain point, the rate of decrease slows significantly. The point where the curve shows a noticeable bend (the “elbow”) represents the optimal balance between model complexity and variance reduction.

In this study: K was tested from 1 to 300. The elbow point was observed around $K = 140$. Beyond $K = 140$, reduction in SSE becomes marginal. Therefore, 140 clusters were

selected, representing 140 optimized bus stop centroids derived from approximately 1,000 observed stopping points. This result indicates that many observed stops were spatially redundant and could be rationalized into a structured and optimized stop system. This confirms that 140 clusters provide a statistically and spatially balanced representation of the observed stop distribution. Then all the 140 clusters are given with different unique name on the basis of famous places or well-known place near them.

3.9. Location Allocation Method

Location–allocation modelling is a network based spatial optimization technique used to determine the optimal placement of facilities to serve geographically distributed demand points under specified constraints. The method simultaneously addresses two interrelated decisions: the selection of facility locations and the allocation of demand points to those selected facilities. The primary objective is typically to minimize travel impedance (distance, time, or cost) or to maximize service coverage within a predefined service threshold.

In transportation planning, location–allocation models are widely applied for public transport stop planning, depot siting, emergency service allocation, and accessibility optimization. In the present study, the model is applied to optimize public transport stop locations in Tarakeshwor Municipality using network-based walking distance, Origin–Destination (O–D) survey data, and Boarding/Alighting (B/A) passenger counts. The modelling framework aims to improve spatial accessibility, reduce walking distance to transit stops, and rationalize redundant stop locations.

The location–allocation modelling approach applied in this study can be conceptually interpreted as a two-stage linear programming-based optimization process used to determine an efficient configuration of bus stop locations within the study area. Although implemented through the network analysis tools of ArcGIS, the underlying logic reflects sequential optimization steps commonly used in facility location problems.

The first stage of the model focuses on determining the minimum number of stops required to adequately serve the spatial distribution of demand. In this stage, the objective of the optimization procedure is to identify the smallest possible set of bus stops that can cover all demand points within a predefined service distance. This step

essentially establishes the optimal facility quantity, ensuring that the network operates with the minimum necessary number of stops while maintaining accessibility for commuters.

$$\text{Min} \sum_{j \in J} Y_j \dots\dots\dots (3.3)$$

$$\text{Subjected to } \sum_{j \in J} X_{ij} = 1 \quad \forall i \in I \dots\dots\dots (3.4)$$

$$X_{ij} \leq Y_j \quad \forall i, j \dots\dots\dots (3.5)$$

$$X_{ij} \leq a_{ij} \quad \forall i, j \dots\dots\dots (3.6)$$

$$X_{ij}, Y_j \in \{0, 1\}$$

Here,

I = set of demand point, indexed by i

J = set of candidate facilities, indexed by j

Decision variable

Facility opening variable

$$Y_j = \begin{cases} 1, & \text{if stop } j \text{ is opened} \\ 0, & \text{otherwise} \end{cases}$$

Assignment variable

$$X_{ij} = \begin{cases} 1, & \text{if demand } i \text{ is assigned to stop } j \\ 0, & \text{otherwise} \end{cases}$$

a_{ij} = coverage indicator

$$a_{ij} = \begin{cases} 1, & \text{if stop } j \text{ can serve the settlement } i \\ 0, & \text{otherwise} \end{cases}$$

The second stage focuses on identifying the most appropriate spatial locations for these stops by minimizing the associated access cost between demand points and selected facilities. Once the feasible number of stops is determined, the optimization process allocates demand points to candidate stop locations in a manner that minimizes the overall access cost, typically represented by walking distance along the road network. This stage ensures that the selected stops are positioned at locations that provide the most efficient spatial coverage and accessibility for users.

$$\min \sum_{i \in I} \sum_{j \in J} W_i C_{ij} X_{ij} \dots\dots\dots (3.7)$$

Subjected to all previous constraints;

$$\sum_{j \in J} Y_j = P^*$$

Then the model is subjected to:

$$\sum_{j \in J} X_{ij} = 1 \quad \forall i \dots\dots\dots(3.8)$$

$$X_{ij} \leq Y_j \quad \forall i, j \dots\dots\dots(3.9)$$

$$X_{ij} \leq a_{ij} \quad \forall i, j \dots\dots\dots(3.10)$$

$$\sum_{j \in J} Y_j = P^*$$

$$X_{ij}, Y_j \in \{0,1\}$$

3.10. Model Types Applied in The Study

Three principal location–allocation models are relevant to this research.

3.10.1. P Median Model

The P median model minimizes the total weighted walking distance between passengers and bus stops. This model is particularly suitable for transit stop optimization because it directly reduces access impedance for passengers. Given the availability of B/A data, demand weights were incorporated into the model to ensure that high volume locations received priority in the optimization process.

3.10.2. Maximal Coverage Model

The maximal coverage model seeks to maximize the total demand served within a specified service distance. In this study, a walking threshold of 400 meters was adopted as the acceptable service standard. Demand points located within 400 meters network distance of a selected stop are considered covered. This model is directly linked to the service area analysis conducted earlier and is used to evaluate accessibility performance.

3.10.3. Set Covering Model

The set covering model minimizes the number of stops required to cover all demand within the defined service threshold. Although not the primary optimization approach in this study, it provides a theoretical basis for stop rationalization and elimination of redundant facilities.

3.10.4. Model Inputs

The model inputs were carefully prepared to ensure consistency and analytical validity. The model is prepared with the length as impedance and problem type as minimize facilities. And the distance of 400m is given as the impedance cut off for the analysis.

3.10.5. Demand Points

Demand points were generated using Boarding/Alighting counts. Passenger volumes were aggregated and assigned as weights to demand nodes. In areas with dense spatial distribution, clustering techniques were used to group nearby demand points for computational efficiency.

3.10.6. Candidate Facility Locations

Candidate locations included both existing bus stops and potential new stop locations generated along the road network at defined spatial intervals. These candidate sites formed the feasible solution space for facility selection. All the initial stops obtained after K-means clustering are taken as the initial candidate stops for the analysis.

3.10.7. Network Dataset

A network dataset was constructed using road centreline data projected in UTM Zone 45N. The impedance attribute was defined as walking distance in meters. All the roads networks were obtained from open street maps along with open turbo and were topologically corrected and converted in UTM 45N for data uniformity. Network based impedance was used instead of Euclidean distance to ensure realistic accessibility measurement.

3.10.8. Service Standard

As mentioned earlier walking accessibility threshold of 400 meters was adopted as the service standard. All coverage-based evaluations were performed using network distance less than or equal to 400 meters. And all the demand points with in the 400m are considered as the covered as they get services from existing public transportation services.

3.10.9. Built up Area

In the first location–allocation model, built-up areas were used as proxies for travel demand. A total of 13,654 built-up polygons were collected from OpenStreetMap (OSM) and Overpass Turbo, imported into google earth and corrected manually if required then digitized in ArcGIS 10.8, and projected to UTM Zone 45N for consistency with the network dataset. Since the model requires point inputs, centroid points were generated from all polygons to represent the spatial distribution of settlement structures within Tarakeshwor Municipality. Built-up areas were selected because they indicate population concentration and potential trip generation, providing a practical substitute for unavailable household-level demand data.

3.10.10. Schools

In the second location–allocation model, schools were used as demand points to represent major institutional trip generators within Tarakeshwor Municipality. A total of 52 schools were identified using OpenStreetMap and municipal records, then mapped as point features in ArcGIS 10.8 and projected to UTM Zone 45N for compatibility with the road network dataset. Schools were treated as a separate demand category because they generate regular and concentrated travel demand, especially during peak hours, and students form an important share of public transport users. Including school locations in the model helped assess the accessibility of educational facilities and identify areas requiring better transit service.

3.10.11. Government Offices

In the third scenario, government offices were incorporated as demand points to represent administrative and public service trip generators within Tarakeshwor Municipality. All the ward offices were plotted and the centre of municipal offices are taken as the government service providers. These points were directly used as demand nodes in the location–allocation model. Government offices were selected because they generate regular and mandatory trips related to administrative services, employment, and public service access. Ensuring adequate public transport accessibility to such institutions is important for improving service reach, reducing dependency on private vehicles, and enhancing inclusive access to essential civic functions.

3.10.12. Hospitals

In another modelling scenario, health posts and other health service providers were incorporated as demand points to represent essential healthcare trip generators within Tarakeshwor Municipality. Since such facilities are limited in number within the study area, a total of 10 health service providers were identified through OpenStreetMap (OSM) data and field verification with the assistance of local residents. The geographic locations of these facilities were mapped as point features and converted into UTM-45N then directly integrated into the location–allocation model as demand nodes. Health facilities were included because access to proper and easy medical services is a fundamental component of equitable urban service provision. Ensuring adequate public transport connectivity to health posts and clinics is particularly important for vulnerable and low-income populations who rely heavily on public transit. Incorporating these facilities into the model enables evaluation of how effectively both existing and optimized stop configurations support access to essential healthcare services.

3.11. Weighted Integration of Candidate Bus Stops for Final Stop Selection

Candidate bus stops were initially identified through location–allocation analysis conducted separately for four categories of demand-generating points of interest (POIs), namely built-up (residential) areas, educational institutions, healthcare facilities, and government service centres. This process resulted in multiple sets of optimized stop locations corresponding to each category.

To develop a unified stop system, all candidate stops were merged into a single spatial layer and examined for spatial redundancy. Due to the independent optimization of each category, several stops were observed to be either overlapping or located within a short distance of one another. Such redundancy indicated the need for a systematic approach to consolidate these stops into a single, demand-responsive network.

To address this issue, a demand-based weighting approach was adopted. The weighting framework was developed based on the concept of trip generation potential associated with different land-use types, as discussed in the study. Trip Generation Rates of Land Uses in a Developing Country City .(Ahmed.et.al 2020) demonstrates that different land use categories contribute unevenly to travel demand, with significant variation in trip generation intensity across land uses. In particular, the study highlights that trip

generation is influenced by the functional characteristics of land use, such as activity type, user volume, and temporal variation in demand.

Accordingly, the weight for each land-use category was calculated using the ratio of its trip generation rate to that of residential land use. Based on this method, residential areas were assigned a base weight of 1.0, while the corresponding weights for educational, healthcare, and office land uses were calculated as 6.55, 7.46, and 4.97 respectively. These values reflect the significantly higher trip generation potential of non-residential land uses compared to residential areas, as observed in the referenced study (Ahmed.et.al, 2020). The derived weights were subsequently used to evaluate and prioritize overlapping candidate bus stops, ensuring that locations associated with higher trip-generating land uses were given greater importance in the final stop selection process and the final set of optimized stops were obtained.

3.12. Dwell Time Estimation Method

Dwell time is “the time in seconds that a transit vehicle is stopped for the purpose of serving passengers. It includes the total passenger service time plus the time needed to open and close doors” (HCM 1985). It is a key operational parameter in transit planning as it directly influences vehicle travel time, schedule adherence, and overall route performance. Levisons (1983) & Dueker (2004) study on transit time performance reported dwell time as:

$$D = 5 + 2.75 \times (B + A) \dots \dots \dots (3.11)$$

where D is the estimated dwell time in seconds,

B is the total number of boarding passengers recorded during the survey period,

A is the total number of alighting passengers,

and the constant term of 5 seconds represents the minimum operational time required for door opening, passenger movement initiation, and vehicle deceleration and acceleration regardless of the passenger load. The coefficient of 2.75 seconds per passenger reflects the average time consumed per boarding or alighting movement under typical urban bus operating conditions.

This formulation is consistent with standard dwell time estimation approaches widely applied in transit operations research, in which total dwell time is modelled as a linear function of passenger activity (boarding plus alighting counts), with an additive fixed time component accounting for door cycle time and vehicle stopping mechanics. The formula was applied uniformly across all regular stops in the dataset.

For bus park stops and fixed terminal locations, namely Prithivi Narayan School, Goldhunga Bus Stop, Sangla Buspark, Jitpur Bus Park, Kokali Check Post, and Machhapokhari Chowk, dwell time is governed by scheduled departure intervals and operator protocols rather than passenger counts alone. These stops were identified separately in the dataset with appropriate remarks. Machhapokhari Chowk, serving as the fixed terminal endpoint, was assigned a minimum dwell value of 5 seconds as a placeholder, since actual terminal dwell time is determined by headway and turnaround scheduling, which is outside the scope of the current stop-level analysis.

3.13. Operational Assessment of Optimized Bus Stops

The second specific objective of this study is to analyse the performance of the optimized bus stops under actual field conditions using boarding–alighting data. To achieve this, three inter-related analyses were carried out: estimation of dwell time at each optimized stop from field-collected boarding–alighting counts; estimation of peak bus arrival frequency at each stop using a route-based simulation approach; and comparison of the estimated bus capacity per berth per hour against the peak bus frequency to assess whether the single-berth configuration at each stop is operationally adequate. This section describes the methodology for deriving peak bus frequency through simulation.

Public transport services in Tarakeshwor Municipality do not operate under a formal published timetable. Operators follow approximate headways derived from fleet size and route length, but no official schedule data is available against which stop-level bus arrival frequency can be directly measured. To overcome this, a route-based simulation model was developed to generate a representative bus arrival timetable for all 11 routes serving the municipality during the morning peak period (8:00 AM to 11:00 AM). The model used route-level operational data obtained from operator surveys specifically fleet size per route, average headway, and route travel time, as collected from the four

operating associations and presented in Tables 3.2 to 3.5 as inputs, and generated simulated bus arrival times at each stop for every bus trip within the service window. The simulation assigned departure times to individual buses based on the headway of each route and propagated these through all stops along the route using the average cumulative travel time to each stop, derived from field-observed reference trips. The detailed computational logic of the simulation is presented in the Annex.

3.14. Bus Stop Capacity Assessment and Comparison

Following the estimation of dwell time at the 53 optimized bus stop locations, a bus stop capacity assessment was carried out to evaluate whether the infrastructure of each stop, represented by a single bus berth, is adequate to handle the volume of buses arriving during the morning peak period. The assessment involves a comparison between the maximum observed bus frequency at each stop and the theoretical maximum bus throughput capacity of a single berth, derived from the estimated dwell time. This comparison enables the identification of stops that may experience operational congestion or require additional berth provision.

3.15. Derivation of Bus Frequency and Berth Capacity

The maximum bus frequency at each stop was determined from the bus tracking simulation, which modelled bus arrivals at all 53 stops during the morning peak period (8:00 AM to 11:00 AM). A route-based simulation was carried out to estimate the bus arrival frequency at each optimized stop, as formal published timetables were not available. The simulation was based on available route information such as departure interval, number of buses, stop sequence, and cumulative travel time along each route. From the known departure intervals between buses, arrival times at different stops were estimated.

The simulated arrivals were then grouped into 15-minute time intervals to identify how many buses reached a particular stop during a specific period. Since some optimized stops are served by more than one route, the number of buses from different routes was aggregated at each stop. This helped determine the peak bus arrival frequency at each optimized stop, which was later compared with the estimated single-berth capacity to assess whether the stop could operate adequately under peak conditions. For each stop,

the highest number of buses observed within any 15-minute interval was extracted and converted into an equivalent hourly frequency by multiplying by four, thereby representing the peak demand condition.

To evaluate whether this demand can be accommodated, the capacity of a single bus berth was estimated based on dwell time. The maximum number of buses that can be served per berth per hour was calculated using:

$$\text{Bus Capacity per Berth per Hour} = 3600 / D$$

where D is the estimated dwell time in seconds at each stop, as derived from the boarding–alighting survey using the formula $D = 5 + 2.75 \times (B + A)$ described, and 3600 is the number of seconds in one hour. This formulation reflects that longer dwell times reduce berth capacity, while shorter dwell times increase the number of buses that can be served per hour.

CHAPTER 4. RESULTS AND DISCUSSIONS

4.1. Overview

This chapter presents the results obtained from the spatial analysis, clustering process, and location–allocation modelling carried out for bus stop optimization in Tarakeshwor Municipality. The findings are discussed according to different demand categories such as built-up areas, schools, government offices, and hospitals. Finally, the integrated optimized stop system and operational assessment based on boarding–alighting analysis are presented.

4.2. Selections of Candidate Stops

Feasible locations through K means clustering was applied to refine the large number of observed boarding–alighting stopping locations into a representative set of feasible bus stop locations. During the field survey, approximately 1,000 stopping points were recorded across different routes within Tarakeshwor Municipality. Due to the informal stop pattern, many of these locations were spatially redundant and closely spaced. To consolidate these points, clustering analysis was performed by testing cluster numbers (K) ranging from 1 to 300 and computing the Sum of Squared Errors (SSE) for each iteration. The elbow method was used to identify the optimal number of clusters by analysing the relationship between SSE and the number of clusters.

The elbow plot indicated that the reduction in SSE became marginal after approximately $K = 140$, suggesting that this value provides a suitable balance between clustering accuracy and spatial representation. Therefore, 140 clusters as shown in Figure 4.1 were selected, and the centroid of each cluster was extracted to represent a feasible candidate bus stop location. These centroid points preserve the spatial distribution of passenger activity while eliminating redundant stops, thereby producing a rationalized set of candidates stop locations. The resulting 140 clustered centroids were subsequently used as candidate facility locations in the GIS based location–allocation model for optimizing bus stop accessibility within the study area.

4.3. Final Bus Stops According to Each Point of Interest

Following the standardization of field raw data and the selection of relevant analysis parameters, optimized stop locations were obtained for four primary demand generators: built up areas, schools, government service providers, and hospitals by using location allocation model.

4.3.1. Built up Area

In the first optimization scenario, built up areas were considered as the primary representation of spatial travel demand within Tarakeshwor Municipality. The Location Allocation model was executed using the previously derived 140 clustered candidate stop locations as facilities and the centroids of built up areas as demand points, with a network impedance cut off of 400 meters. The model was configured with the Minimize Facilities problem type, which aims to identify the minimum number of stops required to serve the maximum possible demand within the defined walking distance threshold.

The optimization results obtained from location allocation model indicate that 51 bus stop locations are sufficient to serve the majority of built up settlements within the municipality under the 400 m accessibility standard as shown in the Figure 4.2. The selected stops are spatially distributed along the existing public transport corridors and are primarily concentrated in densely populated areas where passenger demand is higher. The analysis further shows that approximately 90% of the built up settlement areas fall within the 400 m service coverage, indicating a relatively high level of accessibility provided by the optimized stop configuration.

However, several peripheral settlement clusters remain outside the defined service distance due to their greater distance from the existing road network supporting public transport services. These uncovered areas are mainly located in low density or recently developed residential zones where road connectivity and transit access are limited. Improving accessibility in these areas would require either future road network expansion or the introduction of additional intermediate stops along selected corridors. Overall, the results demonstrate that the optimized stop configuration significantly improves spatial efficiency while maintaining high accessibility for the majority of built up areas within the municipality. The map in Figure 4.2 showing all the stops and selected stops are shown below while the name of all selected stops is tabulated at annex.

4.3.2. School

In the second demand scenario, educational institutions were considered as the primary demand generators to evaluate the accessibility of public transport services for school related travel. The location–allocation analysis indicates that 48 out of 52 identified schools fall within the 400 m walking distance threshold from existing public transport routes. This result demonstrates that the majority of educational facilities in the municipality already have relatively good spatial accessibility to public bus services.

The optimization process identified 24 bus stop locations as the most suitable stops for serving educational institutions across the municipality. As illustrated in Figure 4.3, these selected stops are spatially distributed along the existing public transport corridors and are concentrated in areas with higher densities of educational institutions. In particular, the Nepaltar area exhibits a higher clustering of schools, which results in multiple selected stops located at shorter intervals to adequately serve the concentrated demand.

Overall, the analysis shows that approximately 90% of educational institutions are accessible within the 400 m service distance, indicating that the current road network and transit corridors provide reasonable coverage for school related travel. However, the existing stop pattern around many educational centres is informal and unregulated, with vehicles frequently stopping at arbitrary locations. By formalizing and upgrading the 24 optimized stops identified by the model, safer and more organized boarding locations can be established near educational institutions. This would improve passenger safety, reduce roadside congestion near schools, and enhance the operational efficiency of public transport services in the study area.

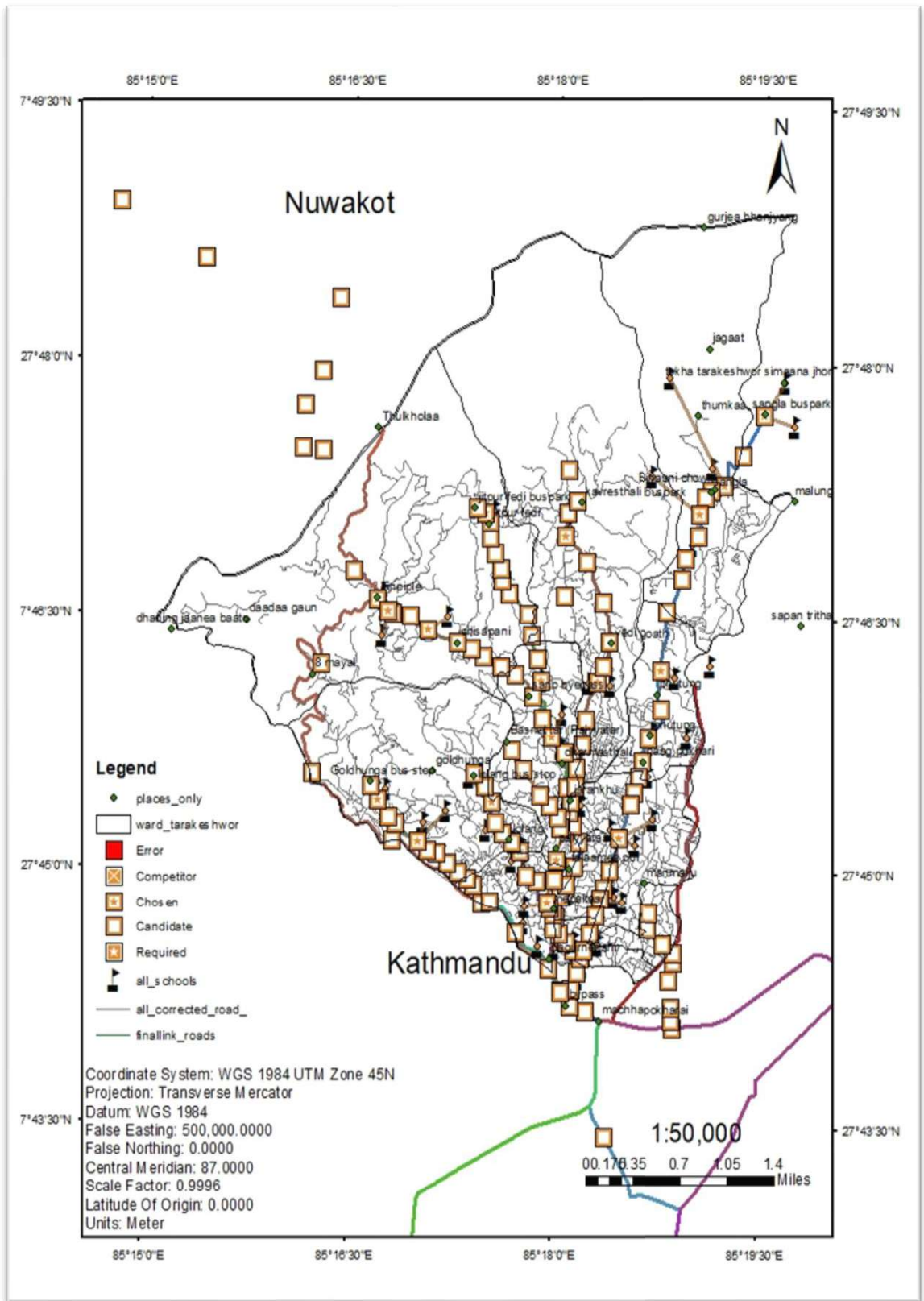


Figure 4.3: Chosen Stops on The Basis of Schools

4.3.3. Government Offices

In the third demand scenario, government service centres were considered as the primary demand points in order to evaluate the accessibility of public transportation for administrative services. The demand dataset consisted of 11 ward offices and one municipal executive office, representing the major government service providers within Tarakeshwor Municipality. The location–allocation model was solved using the previously derived 140 clustered candidate stops with a 400 m walking distance threshold. The results indicate that all government service centres fall within the service range of the existing public transport network, demonstrating adequate spatial accessibility to public bus services.

From the optimization process, 9 bus stops were selected as the most suitable locations for serving government offices. As shown in Figure 4.4, these selected stops are distributed along the major public transport corridors and are positioned to provide efficient coverage of nearby administrative facilities. In certain cases, a single stop serves multiple government offices due to their spatial proximity. For example, Ward 8 and Ward 9 are located close enough to be served by a common stop, and a similar condition is observed for Ward 4 and Ward 11. This shared service coverage reflects the efficiency of the location–allocation model in minimizing the number of required facilities while maintaining accessibility within the specified walking distance. The optimized configuration therefore ensures that government service centres remain accessible while avoiding unnecessary duplication of stops, contributing to a more organized and efficient public transport stop system within the municipality.

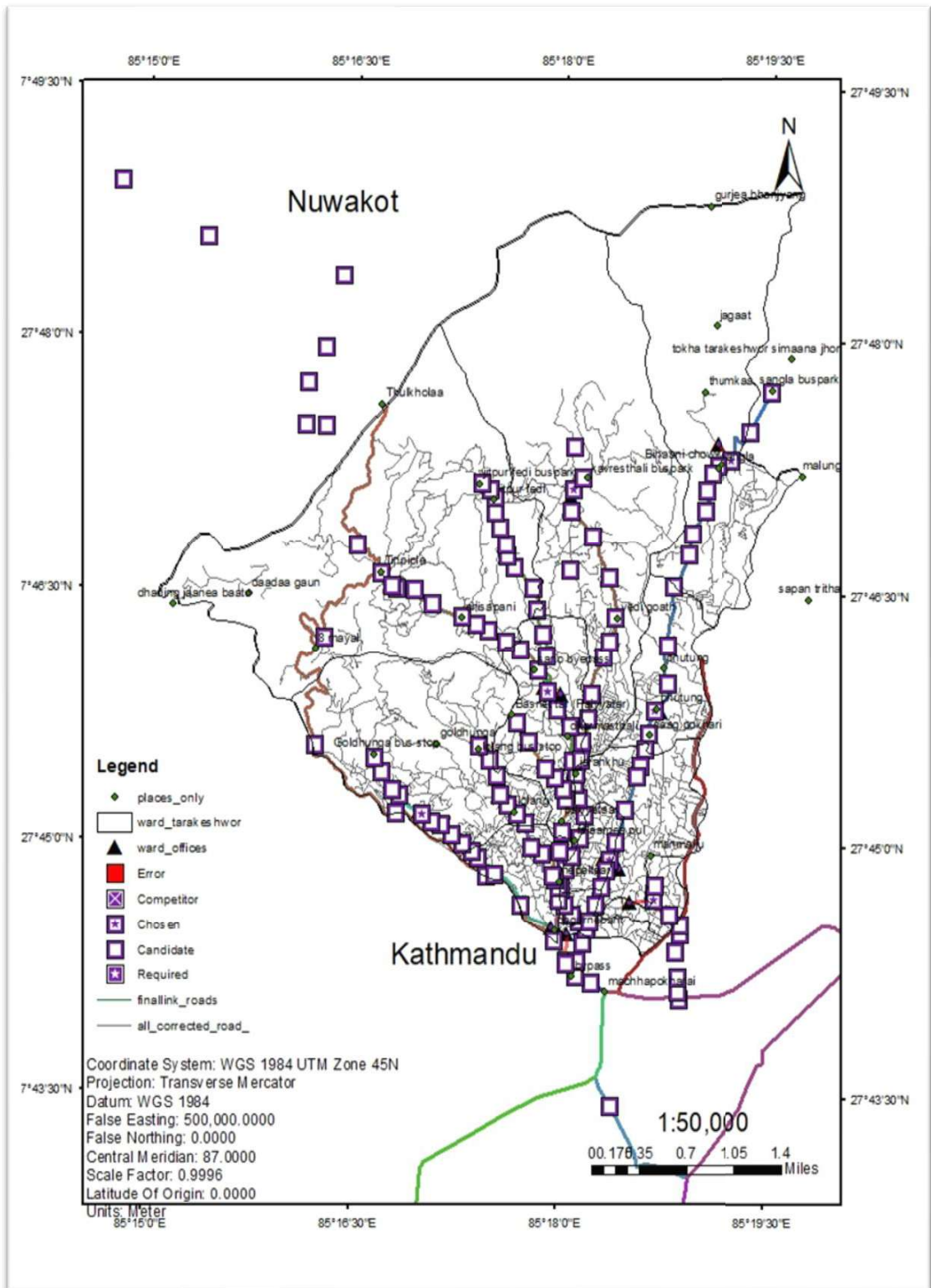


Figure 4.4: Chosen Stops on The Basis of Government Offices

4.3.4. Hospitals

In the fourth demand scenario, health service providers were considered as demand points to assess the accessibility of public transportation to basic healthcare facilities. The dataset included approximately 10 major health service providers, consisting primarily of governmental health posts and ward health clinics that provide basic medical services within Tarakeshwor Municipality. The location–allocation model was solved using the previously generated candidate bus stop locations, with a 400 m walking distance threshold along the road network.

The results indicate that all identified health service providers fall within the service coverage of the existing public transport network, demonstrating adequate accessibility to healthcare facilities through public bus services. The optimization process selected 9 bus stops as the most appropriate stops for serving the identified health facilities. As illustrated in Figure 4.5, these selected stops are distributed along the main transit corridors and are positioned to provide effective coverage to nearby health posts

In some cases, a single stop serves more than one health facility due to their spatial proximity. For example, health posts located in Ward 8 and Ward 9 are served by a common bus stop because of their short inter distance. This reflects the efficiency of the location–allocation model in minimizing the number of required stops while maintaining accessibility within the defined walking threshold. The resulting stop configuration therefore ensures that essential healthcare services remain accessible through public transportation while avoiding unnecessary duplication of stop infrastructure.

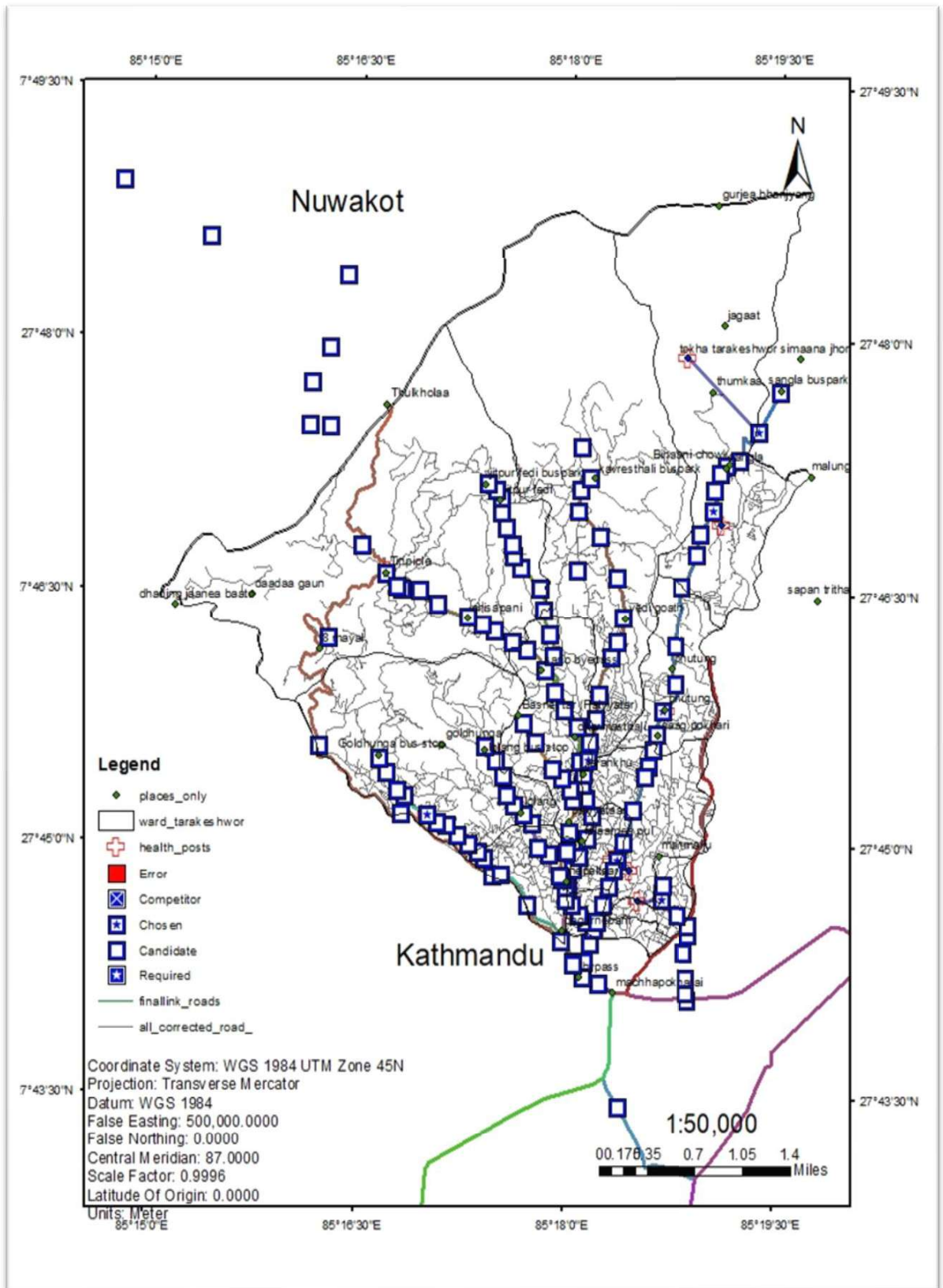


Figure 4.5: Chosen Stops on The Basis of Hospitals

4.4. Final Optimized Stops

To quantify the relative importance of different demand-generating land uses, a weighting scheme was developed based on trip generation characteristics reported in the study *Trip Generation Rates of Land Uses in a Developing Country City*. The study provides average person trip generation rates (per hour per 1,000 square feet) for different land-use categories, indicating the relative intensity of travel demand generated by each category. In order to make these values comparable and applicable within the present study, the reported trip generation rates were converted into relative weights by normalizing them with respect to the residential land-use category, which was considered as the baseline demand generator. This normalization approach allows the expression of all land-use categories in terms of their relative contribution to travel demand compared to residential areas. For this the weightage of residential area was taken as 1, similarly the value for educational, health care and government offices were calculated as 6.55, 7.46 and 4.97 respectively.

A total of 53 stops were obtained as the final set of optimized bus stops. These finalized stops, derived from the location–allocation model, were mapped using a digital platform as illustrated in the Figure 4.6. And the distance between the stops is calculated and presented in the Table 4-1. The analysis shows that most of the optimized stops are located within an acceptable spacing range of around 400 m. However, some stops along the western part of the municipality, particularly on the Ranipauwa–Machhapokhari route, have relatively longer spacing. This is mainly because the route passes through the Nagarjun forest area, where there are no significant human settlements or demand-generating activities. Therefore, wider spacing in this section is considered reasonable. The complete list of finalized stop names is provided in the Annex.

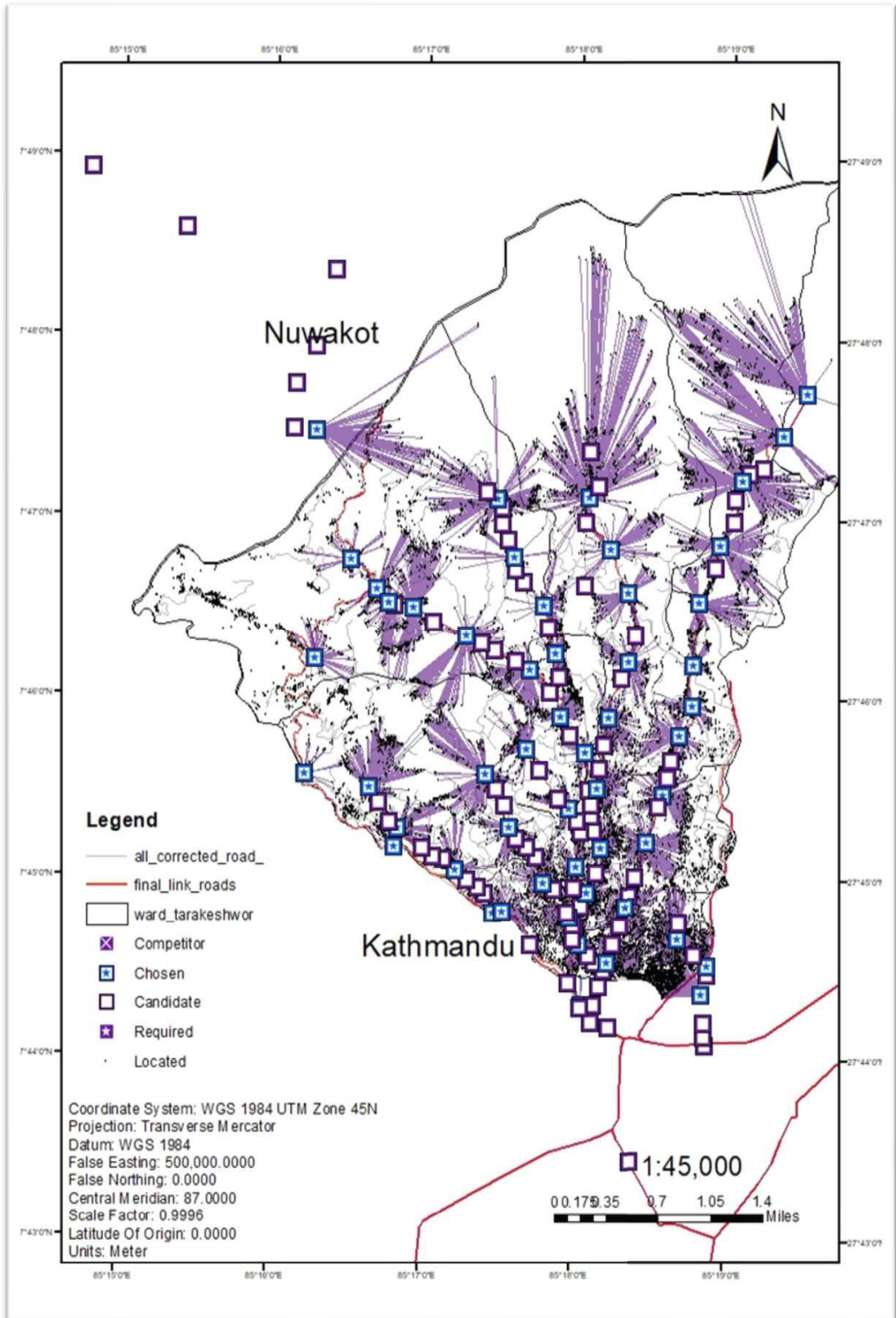


Figure 4.6: Final Optimized Stops

Table 4-1: Distance Between the Nearest Stops

Name of stops		Distance (m)
From	To	
Goldhunga bus stop	Saint jopsep	519
Saint jopsep	SS sunchadi pasal	790
SS sunchadi pasal	Ghumba aagadi	649
Ghumba aagadi	Machhapokhari Chowk	1090
Prithivi narayan school	Nayabasti	622
Nayabasti	Lolang Height	717
Lolang Height	Nepaltar driving school	468
Basnet tar	Jorganesh mandir	713
Jorganesh mandir	Sunflower academy aagade	652
Sunflower academy aagade	Nepaltar driving school	567
Kokali Check Post	Teenpipla tala	241
Teenpipla tala	Ghimire chowk	753
Ghimire chowk	Chisapani chowk	612
Chisapani chowk	Prakriti wood suppliers	783
prakriti wood suppliers	Chauki	679
Chauki	Sk Hardware Jharankhu	512
Sk Hardware Jharankhu	Jarankhu	469
Devisthali	Sarkaridham Kavresthali	632
Sarkaridham Kavresthali	Padamsal Height Kavresthali	773
Padamsal Height Kavresthali	Dhakaltar North	636
Dhakaltar North	Jarankhu	730
Jarankhu	Shiva Mandir Gairigaun	552
Shiva Mandir Gairigaun	Lambagar	547
Lambagar	Sheshmati Shanti Tole	567
Sheshmati Shanti Tole	Eureka school	402
Nepaltar driving school	Sheshmati Shanti Tole	327
Sheshmati Shanti Tole	Dagurnepani	324
Dagurnepani	Machhapokhari Chowk	586
Sangla buspark	angla buspark tala	520
Sangla buspark tala	Sangla bajar	768
Sangla bajar	Dhaka Agro farm	755
Dhaka Agro farm	Sagar Poultry	625
Sagar Poultry	Halesi Mahadev futung	693
Halesi Mahadev futung	Futung bajar	455
Futung bajar	Phutung school	402
Phutung school	Tusal	662
Tusal	Ktm lincon school	512
Ktm lincon school	Jeevan Jyoti school	690
Jeevan Jyoti school	Eureka school	600
Eureka school	Machhapokhari Chowk	712
Manamaiju North	Manamaiju Bridge	426
Manamaiju Bridge	Tokha North	382
Jitpurfedi 1	Kokali Check Post	512

Name of stops		Distance (m)
From	To	
Kokali Check Post	Tinpiple	1217
Tinpiple	Mudkhu Bhanjyang Bazaar	2817
Mudkhu Bhanjyang Bazaar	Saint Boarding School, Mudkhu	1455
Saint Boarding School, Mudkhu	Mudkhu Bhanjyag 1	1333
Mudkhu Bhanjyag 1	Machhapokhari Chowk	1433

4.5. Boarding–Alighting and Dwell Time Analysis of Optimized Stops

To assess the demand performance of the 53 optimized bus stop locations, a Boarding–Alighting (B/A) survey was conducted during the morning peak period for one direction of travel through Tarakeshwor Municipality, as described in the methodology. The survey yielded stop-level passenger counts from which dwell time was estimated for each stop using the linear formula as mentioned in methodology. The results are presented and discussed in the following subsections.

4.5.1. Stop-wise Boarding, Alighting, and Dwell Time

Table 4-2 presents the boarding, alighting, total passenger activity, and estimated dwell time for all 53 optimized stops surveyed during the morning peak period. The dwell time ranges from a minimum of 5.0 seconds at fixed terminal stops to a maximum of 110.0 seconds at Jharankhu, with an average dwell time of 31.5 seconds across all stops.

Table 4-2: Stop-wise Boarding, Alighting, Total Passengers, and Estimated Dwell Time

Final stops	Total Boarding	Total Alighting	Total	Dwell time
Prithivi narayan School	25	0	25	73.75
Nayabasti	12	2	14	43.5
Lolang Height	6	1	7	24.25
Nepaltar drving school	11	4	15	46.25
Goldhunga bus stop	6	0	6	21.5
saint jopsep	10	0	10	32.5
SS sunchadi pasal	18	6	24	71
Ghumba aagadi	8	1	9	29.75
sangla buspark	4	0	4	16

Final stops	Total Boarding	Total Alighting	Total	Dwell time
sangla buspark tala	1	0	1	7.75
Sangla bajar	22	0	22	65.5
Dhakal Agro farm	5	0	5	18.75
Sagar poultry	1	0	1	7.75
Halesi Mahadev futung	1	0	1	7.75
Futung bajar	2	2	4	16
Phutung school	7	1	8	27
Tusal	8	1	9	29.75
Ktm lincon school	4	2	6	21.5
Jeevan Jyoti school	4	0	4	16
Eureka school	3	4	7	24.25
Jitpur Bus Park	17	0	17	51.75
SSSB Suppliers Phedi	7	1	8	27
Gas One Pvt. Ltd.	11	5	16	49
Fedi	8	3	11	35.25
Kavresthali Chowk	37	0	37	106.75
Devisthali	6	0	6	21.5
Sarkaridham Kavresthali	9	2	11	35.25
Padamsal Height Kavresthali	14	3	17	51.75
Dhakaltar North	9	2	11	35.25
Jharankhu	27	11	38	109.5
Manamaiju North	10	0	10	32.5
Manamaiju Bridge	9	0	9	29.75
Tokha North	8	0	8	27
Basnet tar	7	0	7	24.25
Jorganesh mandir	9	0	9	29.75
sunflower academy aagade	7	3	10	32.5
Jitpurfedil	1	0	1	7.75
Kokali Check Post	2	0	2	10.5
Tinpiple	5	0	5	18.75

Final stops	Total Boarding	Total Alighting	Total	Dwell time
Mudkhu Bhanjyang Bazaar	12	0	12	38
Saint Boarding School	2	0	2	10.5
Mudkhu Bhanjyag 1	3	0	3	13.25
Kokali Check Post	6	0	6	21.5
Teenpiple tala	1	0	1	7.75
Ghimire chowk	4	0	4	16
Chisapani chowk	8	0	8	27
prakriti wood suppliers	4	1	5	18.75
Chauki	14	7	21	62.75
Sk Hardware Jharankhu	3	1	4	16
Shiva Mandir Gairigaun	24	13	37	106.75
Lambagar	15	9	24	71
Sheshmati Shanti Tole	13	18	31	90.25
Eureka school	2	8	10	32.5
Machhapokhari Chowk			0	5

4.5.2. Analysis of Demand Distribution Across Optimized Stops

The stop-level demand data reveals a distinctly uneven distribution of passenger activity across the 53 optimized stops, which is characteristic of peri-urban public transport networks where a small number of high-activity focal points coexist with a large number of lightly loaded stops distributed across lower-density corridors.

Nine stops recorded a total passenger activity of 20 or more during the morning peak survey period, representing the highest-demand segment of the optimized network. These stops, in descending order of total activity, are: Jharankhu (38 passengers, 109 seconds dwell time), Kavresthali Chowk (37 passengers, 106 seconds), Shiva Mandir Gairigaun (37 passengers, 106 seconds), Sheshmati Shanti Tole (31 passengers, 90 seconds), Prithivi Narayan School (25 passengers, 73 seconds), SS Sunchadi Pasal (24 passengers, 71 seconds), Lambagar (24 passengers, 71 seconds), Sangla Bajar (22 passengers, 65.5 seconds), and Chauki (21 passengers, 62 seconds).

These high-demand stops are spatially distributed across different corridors of Tarakeshwor Municipality and correspond to locations identified as significant demand generators in the location–allocation model described earlier. Jharankhu and Sano bypass, in particular, serve as convergence points for multiple residential clusters and are located in wards with dense built-up settlement, consistent with the built-up area demand scenario used in the spatial model. The concentration of boarding activity at Prithivi Narayan School reflects its function as a major buspark and trip-generating node at the start of the route, while Sheshmati Shanti Tole, with 13 boardings and 18 alightings, indicates a high interchange function with significant two-directional passenger movement.

At the lower end of the demand spectrum, seven stops recorded a total passenger activity of 2 or fewer during the survey period. These are: Sangla Buspark Tala (1 passenger), Sagar Poultry (1 passenger), Halesi Mahadev Futung (1 passenger), Jitpurfedi 1 (1 passenger), Teenpiple Tala (1 passenger), Kokali Check Post (2 passengers), and Saint Boarding School (2 passengers). These stops carry minimal passenger loads during the morning peak inbound direction. However, it should be noted that for equal distribution and easy accessibility of people these stops are also very important. And while observing the built-up points it is seen that these places are on the verge of being saturate in near futures

4.5.3. Interpretation of Dwell Time and Operational Implications

The average dwell time of 31.5 seconds estimated across all 53 optimized stops indicates that the proposed stop configuration maintains a manageable per-stop delay under morning peak inbound conditions. This figure is consistent with average dwell times observed at informal stops in comparable South Asian peri-urban bus operations, where per-stop delays typically range depending on passenger volumes and vehicle type. The relatively low average reflects the fact that a majority of the 53 stops serve moderate to low passenger loads, with only a minority of high-demand stops contributing dwell times exceeding 60 seconds.

The stops with the highest estimated dwell times, namely Jharankhu, Kavresthali Chowk, and Shiva Mandir Gairigaun, are the most time-consuming stops in the network during the morning peak. These stops should be prioritized for adequate physical infrastructure, including kerb improvements, wide and multiple bus bays, proper pedestrian waiting areas, and clear stop markings, to facilitate smooth and safe boarding and alighting

movement. Appropriate stop design at these locations will be critical for ensuring that actual dwell times do not exceed the estimated values and contribute disproportionately to overall route travel time.

The consistency between the spatial distribution of high-demand stops identified through the B/A survey and the demand nodes used in the location–allocation model provides empirical validation of the optimization approach. Stops that recorded high passenger activity during the field survey coincide with locations near the built-up area centroids, school clusters, and service facility nodes that were incorporated as demand inputs in the GIS-based model. This agreement between modelled demand and observed passenger activity demonstrates that the location–allocation framework effectively captured the underlying spatial demand structure of the study area.

4.6. Bus Stop Capacity Assessment Results

The bus stop capacity comparison for all 53 optimized stop locations, based on the methodology described earlier. Table 7 summarizes the maximum buses observed per 15-minute interval, the equivalent maximum hourly bus frequency, the estimated bus capacity per berth per hour derived from the dwell time formula, and the resulting operational status for each stop.

The bus scheduling simulation results indicate that bus arrivals are unevenly distributed across the study period. While the overall number of buses operating within the selected time window remains consistent with the scheduled frequency, the interval-based analysis reveals significant fluctuations in arrival patterns. Certain time intervals exhibit a high concentration of bus arrivals, whereas others show minimal or no activity. This uneven distribution suggests that buses are not maintaining consistent headways throughout the route, leading to irregular service patterns.

The analysis of bus frequency at individual stops demonstrates notable variation in the number of buses observed within each interval. Some stops consistently record higher bus counts, particularly during peak intervals, while others experience relatively stable or low activity. Stops located further along the route tend to show higher variability in bus frequency compared to upstream stops. This indicates that disruptions accumulate as

buses progress along their routes, resulting in increased irregularity at downstream locations.

Table 4-3: Bus Stop Capacity Comparison

S.N.	Stop Name	Max Buses (15 min)	Max Buses (1 hour)	Bus Capacity per Berth/hr	Status
1	Prithivi Narayan School	2	8	48	Adequate
2	Nayabasti	2	8	82	Adequate
3	Lolang Height	2	8	148	Adequate
4	Nepaltar Driving School	2	8	77	Adequate
5	Goldhunga Bus Stop	1	4	167	Adequate
6	Saint Joseph	1	4	110	Adequate
7	SS Sunchadi Pasal	1	4	73	Adequate
8	Ghumba Aagadi	1	4	121	Adequate
9	Sangla Buspark	3	12	225	Adequate
10	Sangla Buspark Tala	3	12	464	Adequate
11	Sangla Bajar	3	12	66	Adequate
12	Dhakal Agro Farm	3	12	192	Adequate
13	Sagar Poultry	3	12	464	Adequate
14	Halesi Mahadev Futung	3	12	464	Adequate
15	Futung Bajar	3	12	225	Adequate
16	Phutung School	3	12	133	Adequate
17	Tusal	3	12	121	Adequate
18	KTM Lincoln School	3	12	167	Adequate
19	Jeevan Jyoti School	3	12	225	Adequate
20	Eureka School	3	12	148	Adequate
21	Jitpur Bus Park	3	12	69	Adequate

S.N.	Stop Name	Max Buses (15 min)	Max Buses (1 hour)	Bus Capacity per Berth/hr	Status
22	SSSB Suppliers Phedi	3	12	133	Adequate
23	Gas One Pvt. Ltd.	3	12	77	Adequate
24	Fedi	3	12	102	Adequate
25	Kavresthali Chowk	6	24	33	Near Capacity
26	Devisthali	6	24	167	Adequate
27	Sarkaridham Kavresthali	6	24	102	Adequate
28	Padamsal Height Kavresthali	6	24	69	Adequate
29	Dhakaltar North	6	24	102	Adequate
30	Jharankhu	6	24	32	Near Capacity
31	Manamaiju North	2	8	110	Adequate
32	Manamaiju Bridge	2	8	121	Adequate
33	Tokha North	2	8	133	Adequate
34	Basnet Tar	1	4	148	Adequate
35	Jorganesh Mandir	1	4	121	Adequate
36	Sunflower Academy Aagade	1	4	110	Adequate
37	Jitpurfedi 1	1	4	464	Adequate
38	Kokali Check Post	3	12	342	Adequate
39	Tinpiple	1	4	192	Adequate
40	Mudkhu Bhanjyang Bazzar	1	4	94	Adequate
41	Saint Boarding School	1	4	342	Adequate
42	Mudkhu Bhanjyang 1	1	4	271	Adequate
43	Machhapokhari Chowk	–	–	720	Terminal

S.N.	Stop Name	Max Buses (15 min)	Max Buses (1 hour)	Bus Capacity per Berth/hr	Status
44	Teeniple Tala	2	8	167	Adequate
45	Ghimire Chowk	2	8	464	Adequate
46	Chisapani Chowk	2	8	225	Adequate
47	Prakriti Wood Suppliers	2	8	133	Adequate
48	Chauki	5	20	192	Adequate
49	SK Hardware Jharankhu	5	20	57	Adequate
50	Shiva Mandir Gairigaun	11	44	225	Adequate
51	Lambagar	11	44	33	Over Capacity
52	Sheshmati Shanti Tole	11	44	50	Near Capacity
53	Eureka School (Inner)	3	12	39	Adequate

Maximum Bus Frequency vs. Capacity per Berth per Hour

Out of the 53 stops for which bus frequency data is available, 52 stops (98.1%) operate within the theoretical capacity of a single bus berth during the morning peak period, indicating that the overall configuration of the 52 optimized stops is operationally sound and adequate under existing service frequencies. Only one stop, Lambagar, was identified as exceeding single-berth capacity, and three additional stops Kavresthali Chowk, Jharankhu, and Sheshmati Shanti Tole were found to be operating near capacity, warranting close monitoring as demand grows.

4.6.1. Over-Capacity Stop: Lambagar

Lambagar is the only stop in the optimized network where the observed peak bus frequency (44 buses/hour) exceeds the estimated single-berth capacity (33 buses/hour). This is due to the convergence of multiple high-frequency routes and relatively high passenger activity (15 boarding and 9 alighting), resulting in an estimated dwell time of 65 seconds. The excess demand indicates potential congestion, queuing, and delays during peak periods. To address this, provision of an additional bus berth or

implementation of operational measures such as route headway staggering is recommended.

The bus stop capacity assessment confirms that the 53-stop optimized configuration is operationally feasible under morning peak conditions for the large majority of stops. One stop (Lambagar) requires an additional bus berth due to demand exceeding single-berth capacity; three stops (Jharankhu, Kavresthali Chowk, and Sheshmati Shanti Tole) are near capacity and require monitoring and infrastructure planning; and the remaining stops have adequate to substantial berth capacity surplus. Taken together, these results validate the demand-responsive nature of the optimized stop layout and provide actionable guidance for prioritizing physical infrastructure investments at specific locations within Tarakeshwor Municipality.

CHAPTER 5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

This study evaluated and optimized bus stop accessibility in Tarakeshwor Municipality using a GIS-based approach integrated with network analysis and a location–allocation model. By combining primary data such as boarding alighting surveys and route tracking with secondary spatial data, an initial set of nearly 1,000 informal stopping points was refined into 140 candidate locations, and further optimized into a final set of 53 bus stops. The results show that the existing public transport system is spatially inefficient due to unplanned and redundant stopping practices. The analysis also showed that the optimized public transportation system provides approximately 90% coverage to the existing built-up areas within the adopted walking distance threshold. The optimized stop configuration will certainly reduce redundancy, and effectively serves most demand points within a 400 m walking distance, particularly for residential areas and key service facilities. However, some peripheral areas remain underserved due to limited road connectivity.

The bus stop capacity assessment further demonstrated that 52 of the 53 stops for which bus frequency data was available can accommodate peak bus demand within a single berth, confirming the operational adequacy of the optimized stop configuration. The single exception, Lambagar, where the maximum bus frequency of 44 buses per hour exceeds the estimated single-berth capacity of 33 buses per hour, is identified as requiring an additional bus berth or a nearby supplementary stop to manage peak operations effectively. Stops at Jharankhu, Kavresthali Chowk, and Sheshmati Shanti Tole were found to be operating near capacity and are recommended for priority infrastructure investment as service demand continues to grow.

Overall, the study demonstrates that GIS-based methods provide a reliable and practical framework for improving bus stop planning and supporting efficient public transport development in growing urban areas.

5.2. Recommendations

Based on the findings of this study, it is recommended that Tarakeshwor Municipality implement a formal bus stop planning system using the optimized locations identified through the GIS location–allocation model. The proposed stops should be designated as official boarding and alighting points along the major public transport corridors to reduce informal stopping practices and improve operational efficiency. Priority should be given to stops serving high demand land uses such as residential clusters, schools, health facilities, and government offices, as these locations generate significant passenger movement and require safe and organized access to public transport services. The establishment of clearly defined stop locations, supported by basic infrastructure such as signage, designated stopping zones, and pedestrian access improvements, would improve passenger safety, operational discipline, and service reliability. As Nepal-specific land-use trip generation rates were not available; therefore, rates from a similar developing-country context were used. However, local travel behaviour and land-use characteristics may differ, so future studies should develop Nepal-specific trip generation rates.

Route extension is also recommended for selected corridors where future service expansion is feasible. In particular, routes such as Lolang–RNAC and Goldhunga–RNAC may be extended to improve public transport coverage in underserved upper hilly areas. Similarly, where possible, routes passing toward Kakani should be realigned or extended through village areas around the Mudkhu Bhanjyang corridor to improve accessibility for settlements currently located away from existing service corridors. Further analysis can be done by taking full 12 hrs boarding alighting data for high accuracy.

REFERENCES

- Adekunte, P. A., Sadiku, M. N. O., & Sadiku, J. O. (2025). Public transportation in developing countries. *International Journal of Trend in Scientific Research and Development*, 9(2), 376–385. <http://www.ijtsrd.com/papers/ijtsrd76344.pdf>
- Asian Development Bank. (2019). Nepal urban transport sector assessment. Asian Development Bank.
- Badami, M. G., & Haider, M. (2007). An analysis of public bus transit performance in Indian cities. *Transportation Research Part A: Policy and Practice*, 41(10), 961–981. <https://doi.org/10.1016/j.tra.2007.06.002>
- Bajracharya, A., & Nakarmi, A. (2021). Network analysis of public transportation in Kathmandu Valley. *Journal of Advanced Transportation*.
- Berg, J., & Ihlström, J. (2019). The importance of public transport for mobility and everyday activities among rural residents. *Social Sciences*, 8(2), Article 58. <https://doi.org/10.3390/socsci8020058>
- Bhattarai, R., & Shahi, P. B. (2021). Multi-modal integration for sustainable mobility in Kathmandu. *Nepal Journal of Civil Engineering*. <https://doi.org/10.9790/1684-1806034759>
- Central Bureau of Statistics. (2021). National population and housing census 2021. Government of Nepal.
- Chew, E. P., & Lee, L. H. (2011). Urban public transport planning: Network design and operational optimization. <https://doi.org/10.2991/iccasm.2012.14>
- Church, R. L. (2025). Charles S. ReVelle (1938–2005): A leader in location modeling and environmental management. In *Great minds in regional science* (Vol. 3, pp. 185–200). Springer Nature Switzerland.

- Delmelle, E. M., & Casas, I. (2012). Identifying bus stop redundancy using GIS-based spatial analysis. *Computers, Environment and Urban Systems*, 36(5), 445–455. <https://doi.org/10.1016/j.compenvurbsys.2012.01.002>
- Delmelle, E. M., Li, S., & Murray, A. T. (2012). Identifying bus stop redundancy: A GIS-based spatial optimization approach. *Computers, Environment and Urban Systems*, 36(5), 445–455. <https://doi.org/10.1016/j.compenvurbsys.2012.01.002>
- Dueker, K. J., Kimpel, T. J., Strathman, J. G., & Callas, S. (2004). Determinants of bus dwell time. *Journal of Public Transportation*, 7(1), 21–40.
- El-Geneidy, A., & Levinson, D. (2006). Access to destinations: Development of accessibility measures. Minnesota Department of Transportation. <http://www.lrrb.org/PDF/200616.pdf>
- El-Geneidy, A., Grimsrud, M., Wasfi, R., Tétreault, P., & Surprenant-Legault, J. (2014). New evidence on walking distances to transit stops: Identifying redundancies and gaps using variable service areas. *Transportation*, 41(1), 193–210. <https://doi.org/10.1007/s11116-013-9508-z>
- Fan, W., & Machemehl, R. B. (2006). Optimal transit route network design problem with variable transit demand: Genetic algorithm approach. *Journal of Transportation Engineering*, 132(1), 40–49. [https://doi.org/10.1061/\(ASCE\)0733-947X\(2006\)132:1\(40\)](https://doi.org/10.1061/(ASCE)0733-947X(2006)132:1(40))
- Farahani, R. Z., Miandoabchi, E., Szeto, W. Y., & Rashidi, H. (2013). A review of urban transportation network design problems. *European Journal of Operational Research*, 229(2), 281–302. <https://doi.org/10.1016/j.ejor.2012.10.009>
- Farewell, R. G., & Marx, E. (1996). Planning, implementation and evaluation of OmniRide demand-driven transit operations: Feeder and flex-route services. *Transportation Research Record*, 1557(1), 1–9. <https://doi.org/10.1177/0361198196155700101>
- Giuffrida, N. (2022). Optimization and machine learning applied to last mile logistics: A review. *Sustainability*, 14(9), Article 5329. <https://doi.org/10.3390/su14095329>

- Giuffrida, N., Binetti, M., Viscio, S., & Ottomanelli, M. (2022). A simplified framework for the equity-based spatial assessment of alternative public transport networks. *Sustainability*, 14(24), Article 16606. <https://doi.org/10.3390/su142416606>
- Hidalgo, D., & Huizenga, C. (2013). Implementation of sustainable urban transport policies. *Research in Transportation Economics*, 40(1), 66–77. <https://doi.org/10.1016/j.retrec.2012.06.034>
- Huang, J., Dou, Y., Qi, S., & Wang, T. (2020). Sustainable development of urban public transportation. <https://doi.org/10.1016/j.scs.2023.104530>
- Ibarra-Rojas, O. J., Delgado, F., Giesen, R., & Muñoz, J. C. (2015). Planning, operation, and control of bus transport systems: A literature review. *Transportation Research Part B: Methodological*, 77, 38–75.
- Japan International Cooperation Agency. (2017). Kathmandu Valley urban transport master plan. JICA.
- Kwan, M. P., Murray, A. T., O’Kelly, M. E., & Tiefelsdorf, M. (2003). Recent advances in accessibility research: Representation, methodology and applications. *Journal of Geographical Systems*, 5(1), 129–138.
- Litman, T. (2025). Evaluating public transit benefits and costs. Victoria Transport Policy Institute.
- Poudel, K. (2025). Bus stop consolidation considering users’ willingness to walk: A case study of Lagankhel–Khokana section [Unpublished thesis/report].
- Shahi, P. B., Adhikari, R., & Joshi, S. (2018). Operational inefficiencies in Kathmandu’s public transport system. *Transportation Research Procedia*.
- Shatnawi, N., Almasri, E., & Haya, A. (2020). Optimization of bus stops locations using GIS techniques and artificial intelligence. *Procedia Manufacturing*, 44, 52–59. <https://doi.org/10.1016/j.promfg.2020.02.204>
- Thapa, R. B., Pradhananga, R., & Shrestha, P. K. (2024). Comparison of travel time reliability of different bus service providers: A case study of Airport to Narayan Gopal Chowk route, Kathmandu. *International Journal on Engineering Technology*, 1(2). <https://doi.org/10.3126/injet.v1i2.66729>

Transportation Research Board. (2016). Highway capacity manual (6th ed.). National Academies Press.

Vuchic, V. R. (2007). Urban transit systems and technology. John Wiley & Sons.

ANNEX A: STOPS

List of Routes with their stops that lies with in municipality

S.N	Route Name	Stops
1	Lolang-Machhapokhari	Prithivi narayan School, lolang bus stop tala, Jhulafat, Nayabasti, Bohoratar, lolang, deepshikha school, Lolang Height, Jay Nepal chowk, Nepaltar drving school, Nepaltar left, Sesmati left, Bypass chowk, Machhapokhari
2	Goaldhungga-Machhapokhari	Goldhunga bus stop, tilganga mathi, Tilganga eye centre, saint jopsep, satdhara, Anita meat shop, tapari momo, SS sunchadi pasal, J.b nirman suppliers, Meditation centre nera, Ronisha store aagadi, Ghumba aagadi, Mudkhu Bhanjyang Machhapokhari, Bypass, Machhapokhari
3	Jhor-Machhapokhari	sangla buspark, sangla buspark tala, Sangla fat, Bihani chowk, Sangla bajar, Red Cherry bakery, Landmark academy, Dhakal Agro farm, Chimber Pokhari , Sagar poultry, Halesi Mahadev futung, Futung bajar, Phutung school, Naagpokhari, Kalpeshwor samaj, Tusal, Tusal bajar, Ktm lincon school, Him rashmi high school, Dhukka bachat, Kc store, Pashupati kasta udhyog, Eureka school, Nepaltar North, Nepaltar, Balaju Bypass, Bypass Chowk, Maachhapokhari
4	Jitpurfedi-Machhapokhari	Jitpur Bus Park, Fedi Buspark Road, Fedi Chowk, Fedi Agricultural Fsrn, Dakshinkali Furniture Fedi, SSSB Suppliers Phedi, Masalbot Tol, Jitpurfedi, Gas One Pvt. Ltd., Fedi North, Fedi, Guinness School, Sano Bypass, Chauki, Dharmasthali, Sk Hardware Jharankhu, Jarankhu Bridge, Jarankhu Pari (North), Jarakhnu Wari, Nepal Ratna School Gairigaun, Shiva Mandir Gairigaun, Lambagar Falame Pul, Lambagar, CN Mart Shesmati, Sheshmati Naya Pul, Jyoti Bikas Bank Nepaltar, Laxmisunrise Bank Nepaltar, Nepaltar North, Nepaltar, Balaju Bypass, Bypass Chowk , Machhapokhari
5	Kavresthali-Kalnaki	Simleshwor Temple Kavresthali, Kavresthali Bus Stop, Kavresthali Chowk, Peplbot Kavresthali, Devisthali, Sarkaridham Kavresthali, Vedigot Kavresthali, Padamsal Chowk, Dhakaltar North, Dhakaltar South, Dharmasthali, Jharankhu, Jarankhu Bridge, Jarankhu Pari (North), Jarakhnu Wari, Nepal Ratna School Gairigaun, Shiva Mandir Gairigaun, Lambagar Falame Pul, Lambagar, CN Mart Shesmati, Sheshmati Naya Pul, Jyoti Bikas Bank Nepaltar, Laxmisunrise Bank Nepaltar, Nepaltar North, Nepaltar, Balaju Bypass, Bypass Chowk , Machhapokhari
6	Kavresthali-Teaching-Rnac	Simleshwor Temple Kavresthali, Kavresthali Bus Stop, Kavresthali Chowk, Peplbot Kavresthali, Devisthali, Sarkaridham Kavresthali, Vedigot Kavresthali, Padamsal Chowk, Dhakaltar North, Dhakaltar South, Dharmasthali, Jharankhu, Jarankhu Bridge, Jarankhu Pari (North), Jarakhnu Wari, Nepal Ratna School Gairigaun, Shiva Mandir Gairigaun, Lambagar Falame Pul, Lambagar, CN Mart Shesmati, Sheshmati Naya Pul, Jyoti Bikas Bank Nepaltar, Laxmisunrise Bank Nepaltar, Nepaltar North, Nepaltar, Balaju Bypass, Bypass Chowk , Machhapokhari

S.N	Route Name	Stops
7	Kavresthali-Rnac	Simleshwor Temple Kavresthali, Kavresthali Bus Stop, Kavresthali Chowk, Peplbot Kavresthali, Devisthali, Sarkaridham Kavresthali, Vedigot Kavresthali, Padamsal Chowk, Dhakaltar North, Dhakaltar South, Dharmasthali, Jharankhu, Jarankhu Bridge, Jarankhu Pari (North), Jarakhnu Wari, Nepal Ratna School Gairigaun, Shiva Mandir Gairigaun, Lambagar Falame Pul, Lambagar, CN Mart Shesmati, Sheshmati Naya Pul, Jyoti Bikas Bank Nepaltar, Laxmisunrise Bank Nepaltar, Nepaltar North, Nepaltar, Balaju Bypass, Bypass Chowk , Machhapokhari
8	Manamaiju-Rnac	Manamaiju Bus Stop, Manamaiju North, Loktantatrik Chowk, Manamaiju Bridge, Manamaiju, Tokha North, Tokha South, Gongabu 1, Gongabu
9	Payutar-Rnac	Basnet tar, Tallo basnet tar, rabi hair aagade, Jorganesh mandir, paiyatar mathi, sunflower academy aagade, falaame pil pari, Nepaltar arjun health, Nepaltar driving school, Nepaltar left, sesmati left, Bypass Chowk, Machhapokhari
10	Ranipauwa-Rnac	Jitpurfedi 1, Kokali Check Post, Tinpipe, Mudkhu Bhanjyang Bazaar, Saint Boarding School, Mudkhu, Mudkhu Bhanjyag 1, Jamacho Hill Hiking, Mudkhu, Machhapokhari North, Mudkhu Bhanjyang Machhapokhari, Bypass Chowk, Machhapokhari
11	Tinpipe-Rnac	Kokali Check Post, Teenpipe tala, chisapani mathi, Ghimire chowk, Anushree garden resturant, Chisapani chowk, Chisapani tala, Tarakeshwor Petrol Pump, Puspa bina chowk, prakriti wood suppliers, Sano Bypass, Chauki, Dharmasthali, Sk Hardware Jharankhu, Jarankhu Bridge, Jarankhu Pari (North), Jarakhnu Wari, Nepal Ratna School Gairigaun, Shiva Mandir Gairigaun, Lambagar Falame Pul, Lambagar, CN Mart Shesmati, Sheshmati Naya Pul, Jyoti Bikas Bank Nepaltar, Laxmisunrise Bank Nepaltar, Nepaltar North, Nepaltar, Balaju Bypass, Bypass Chowk , Machhapokhari

List of optimized stops obtained from model

a. Builtup

S.N.	Name
1	Tokha North
2	Manamaiju Bridge
3	Manamaiju North
4	Machhapokhari Chowk
5	Sheshmati Shanti Tole
6	Lambagar
7	Shiva Mandir Gairigaun
8	Jarankhu
9	Dhakaltar North

S.N.	Name
10	Sarkaridham Kavresthali
11	Devisthali
12	Kavresthali Chowk
13	Sk Hardware Jharankhu
14	Chauki
15	Fedi
16	Gas One Pvt. Ltd.
17	SSSB Suppliers Phedi
18	Fedi Buspark Road

S.N.	Name
19	Mudkhu Bhanjyag 1
20	Saint Boarding School, Mudkhu
21	Mudkhu Bhanjyang Bazaar
22	Tinpipe
23	Kokali Check Post
24	Jitpurfedi 1
25	Oshu cafe, Tinpipe
26	Padamsal Height Kavresthali
27	Nepaltar driving school
28	sunflower academy aagade
29	Jorganesh mandir
30	Basnet tar
31	Ghumba aagadi
32	SS sunchadi pasal
33	saint jopsep
34	Goldhunga bus stop
35	Lolang Height

S.N.	Name
36	Nayabasti
37	Prithivi narayan school
38	prakriti wood suppliers
39	Chisapani chowk
40	Teenpipe tala
41	sangla buspark
42	Sangla bajar
43	Dhakal Agro farm
44	Sagar Poultry
45	Halesi Mahadev futung
46	Futung bajar
47	Phutung school
48	Tusal
49	Ktm lincon school
50	Jeevan Jyoti school
51	Eureka school

b. Schools

S.N.	Name
1	Nepaltar North
2	Sheshmati Naya Pul
3	Jarakhnu Wari
4	Padamsal Chowk
5	Peplbot Kavresthali
6	Dharmasthali
7	Guiness School
8	Fedi Buspark Road
9	Kokali Check Post
10	Nepaltar arjun health
11	sunflower academy aagade
12	satdhara
13	tilganga mathi
14	deepshikha school
15	Jhulafat

S.N.	Name
16	Anushree garden resturant
17	Teenpipe tala
18	sangla buspark
19	Sangla fat
20	Red Cherry bakery
21	Halesi Mahadev futung
22	Naagpokhari
23	Ktm lincon school
24	Jeevan Jyoti school

c. Ward offices (Governmental Service Providers)

S.N.	Name
1	Manamaiju North
2	Machhapokhari Chowk
3	Kavresthali Chowk
4	Chauki

S.N.	Name
5	Kokali Check Post
6	satdhara
7	Sangla fat
8	Phutung school
9	Dhukka bachat

d. Health posts

S.N.	Name
1	Manamaiju North
2	Jarankhu
3	Kokali Check Post
4	Nepaltar left
5	satdhara
6	sangla buspark tala
7	Landmark academy
8	Phutung school
9	Dhukka bachat

ANNEX B: PSEUDO CODE AND DATA

Pseudo Code of Bus Scheduling Calculations

INPUT:

Reference_Arrivals = baseline arrival pattern per route & stop
Route_Config = parameters (headway, start time, number of buses, offsets)
Route_Stops = mapping of routes → stops sequence
Stops = list of all stops
TimeWindow = simulation duration
Interval = small step (e.g., 1–5 min)

STEP 1: GENERATE BUS SCHEDULE (Bus_Schedule sheet)

For each route:

Read:

- start_time
- headway (time between buses)
- number_of_buses

For bus_index = 1 to number_of_buses:

departure_time = start_time + (bus_index - 1)*headway

Create new bus record

STEP 2: PROPAGATE BUSES ALONG ROUTE (Bus_Arrivals sheet)

For each bus:

Get route from Route_Config

Get ordered stops from Route_Stops

For each stop in sequence:

Lookup travel time from Reference_Arrivals

OR use delta between stops from reference data

arrival_time(stop_n) =

arrival_time(stop_n-1) + travel_time

Store:

(bus_id, route, stop_id, arrival_time)

STEP 3: BUILD TIME INTERVAL GRID

Create intervals across full TimeWindow:

e.g., every 5 minutes

STEP 4: COUNT BUSES AT EACH STOP (Stop_Frequency sheet)

For each stop:

For each interval:

count = 0

For each bus arrival at that stop:

If arrival_time falls within interval:

count += 1

Store:

Stop_Frequency[stop][interval] = count

STEP 5: AGGREGATE RESULTS (All_Stops_Summary sheet)

For each stop:

Calculate:

- Total arrivals
- Average buses per interval
- Peak interval (max buses)
- Possibly standard deviation / variability

STEP 6: OUTPUT VISUALIZATION

VBA code used in bus frequency calculations:

Attribute VB_Name = "Module1"

' =====

' SimulateBusSchedule

' =====

' PURPOSE:

- ' Reads Reference_Arrivals (average cumulative minutes per stop)
- ' and Route_Config (headway, service start/end) then rebuilds
- ' Bus_Schedule with every bus trip for every route, all day.

'

' HOW TO USE:

- ' 1. Open Bus_Tracking_v3.xlsx
- ' 2. Press Alt + F11 ? opens the VBA Editor
- ' 3. In the menu: Insert ? Module
- ' 4. Paste this entire file into the new module

- ' 5. Close the VBA Editor (Alt + Q)
- ' 6. Go to the "Route_Config" sheet
- ' 7. Developer tab ? Insert ? Button (Form Control), draw it on
' the sheet near cell A3, then when prompted assign the macro
' "SimulateBusSchedule"
- ' 8. Click the button to rebuild Bus_Schedule any time you
' change headways or service hours.
- '
- ' NOTE: Save the file as .xlsm (Excel Macro-Enabled Workbook)
' after adding the macro, otherwise it will be lost.

'=====

```
Sub SimulateBusSchedule()

    Dim wsRA As Worksheet
    Dim wsCfg As Worksheet
    Dim wsSched As Worksheet
    Dim lastRowRA As Long
    Dim lastRowCfg As Long
    Dim i As Long, j As Long, schedRow As Long

    Application.ScreenUpdating = False
    Application.Calculation = xlCalculationManual
    Application.StatusBar = "Simulating Bus Schedule..."

    Set wsRA = ThisWorkbook.Sheets("Reference_Arrivals")
    Set wsCfg = ThisWorkbook.Sheets("Route_Config")
    Set wsSched = ThisWorkbook.Sheets("Bus_Schedule")

    '?? Step 1: Force recalculate Reference_Arrivals averages ?
    wsRA.Calculate
    wsCfg.Calculate

    '?? Step 2: Read Reference_Arrivals data ?
```

```

' Columns: A=RouteID, B=RouteName, C=TripNo, D=StopOrder, E=StopName
'     F=Trip1, G=Trip2, H=Trip3, I=Trip4, J=Avg_MinFromStart
lastRowRA = wsRA.Cells(wsRA.Rows.Count, "A").End(xlUp).Row

' Count valid data rows
Dim raCount As Long
raCount = 0
For i = 2 To lastRowRA
    If IsNumeric(wsRA.Cells(i, 1).Value) And wsRA.Cells(i, 1).Value <> "" Then
        raCount = raCount + 1
    End If
Next i

' Load into array: (RouteID, RouteName, StopOrder, StopName, AvgMin)
Dim raData() As Variant
ReDim raData(1 To raCount, 1 To 5)
Dim idx As Long
idx = 0
For i = 2 To lastRowRA
    If IsNumeric(wsRA.Cells(i, 1).Value) And wsRA.Cells(i, 1).Value <> "" Then
        idx = idx + 1
        raData(idx, 1) = CLng(wsRA.Cells(i, 1).Value) ' RouteID
        raData(idx, 2) = wsRA.Cells(i, 2).Value      ' RouteName
        raData(idx, 3) = CLng(wsRA.Cells(i, 4).Value) ' StopOrder
        raData(idx, 4) = wsRA.Cells(i, 5).Value      ' StopName
        raData(idx, 5) = wsRA.Cells(i, 14).Value     ' Avg_MinFromStart
    End If
Next i

' ?? Step 3: Read Route_Config ?
' Rows 6..end = routes (A=RouteID, C=Headway_min, D=ServiceStart, E=ServiceEnd)
lastRowCfg = wsCfg.Cells(wsCfg.Rows.Count, "A").End(xlUp).Row
Dim routeCount As Long
routeCount = 0

```

```

For i = 6 To lastRowCfg
    If IsNumeric(wsCfg.Cells(i, 1).Value) And wsCfg.Cells(i, 1).Value <> "" Then
        routeCount = routeCount + 1
    End If
Next i

' routeData: (RouteID, Headway, SvcStartMins, SvcEndMins)
Dim routeData() As Variant
ReDim routeData(1 To routeCount, 1 To 4)
idx = 0
For i = 6 To lastRowCfg
    If IsNumeric(wsCfg.Cells(i, 1).Value) And wsCfg.Cells(i, 1).Value <> "" Then
        idx = idx + 1
        routeData(idx, 1) = CLng(wsCfg.Cells(i, 1).Value) ' RouteID
        routeData(idx, 2) = CDbL(wsCfg.Cells(i, 3).Value) ' Headway minutes
        ' ServiceStart/End stored as Excel time fractions ? convert to minutes
        Dim sStart As Double, sEnd As Double
        sStart = wsCfg.Cells(i, 4).Value
        sEnd = wsCfg.Cells(i, 5).Value
        routeData(idx, 3) = sStart * 1440 ' minutes from midnight
        routeData(idx, 4) = sEnd * 1440
    End If
Next i

' ?? Step 4: Clear Bus_Schedule and write header ?
wsSched.Cells.Clear
With wsSched
    .Cells(1, 1).Value = "RouteID"
    .Cells(1, 2).Value = "BusID"
    .Cells(1, 3).Value = "RouteName"
    .Cells(1, 4).Value = "StopOrder"
    .Cells(1, 5).Value = "StopName"
    .Cells(1, 6).Value = "ArrivalTime"
    .Cells(1, 7).Value = "DepartureTime"

```

```

.Cells(1, 8).Value = "Dwell_min"

' Style the header row
Dim hdrRange As Range
Set hdrRange = .Range("A1:H1")
hdrRange.Interior.Color = RGB(31, 78, 121)
hdrRange.Font.Color = RGB(255, 255, 255)
hdrRange.Font.Bold = True
End With

' ?? Step 5: Generate schedule ?
schedRow = 2
Dim DWELL As Long: DWELL = 1 ' dwell time at each stop (minutes)

Dim ri As Long
For ri = 1 To routeCount

    Dim curRoute As Long: curRoute = routeData(ri, 1)
    Dim headway As Double: headway = routeData(ri, 2)
    Dim svcStart As Double: svcStart = routeData(ri, 3)
    Dim svcEnd As Double: svcEnd = routeData(ri, 4)
    Dim routeName As String

    ' Collect stops for this route
    Dim stopCount As Long: stopCount = 0
    For i = 1 To raCount
        If raData(i, 1) = curRoute Then stopCount = stopCount + 1
    Next i
    If stopCount = 0 Then GoTo NextRoute

    Dim stopOrders() As Long
    Dim stopNames() As String
    Dim stopAvgMins() As Double
    ReDim stopOrders(1 To stopCount)

```

```

ReDim stopNames(1 To stopCount)
ReDim stopAvgMins(1 To stopCount)
routeName = ""

Dim si2 As Long: si2 = 0
For i = 1 To raCount
    If raData(i, 1) = curRoute Then
        si2 = si2 + 1
        stopOrders(si2) = raData(i, 3)
        stopNames(si2) = raData(i, 4)
        stopAvgMins(si2) = raData(i, 5)
        routeName = raData(i, 2)
    End If
Next i

' Bus departure loop
Dim depMins As Double: depMins = svcStart
Dim busNum As Long: busNum = 1

Do While depMins < svcEnd
    Dim busID As String
    busID = "B" & Format(curRoute, "00") & "-" & Format(busNum, "02")

    For j = 1 To stopCount
        Dim arrMins As Double
        arrMins = depMins + stopAvgMins(j)
        If arrMins > svcEnd + 90 Then Exit For
    Next j

    Dim deptMins As Double: deptMins = arrMins + DWELL

    With wsSched
        .Cells(schedRow, 1).Value = curRoute
        .Cells(schedRow, 2).Value = busID
        .Cells(schedRow, 3).Value = routeName
    End With
    busNum = busNum + 1
    depMins = deptMins

```

```

.Cells(schedRow, 4).Value = stopOrders(j)
.Cells(schedRow, 5).Value = stopNames(j)

Dim arrH As Long, arrM As Long
arrH = Int(arrMins / 60) Mod 24
arrM = CLng(arrMins) Mod 60
.Cells(schedRow, 6).Value = TimeSerial(arrH, arrM, 0)
.Cells(schedRow, 6).NumberFormat = "HH:MM"

```

```

Dim depH As Long, depM As Long
depH = Int(deptMins / 60) Mod 24
depM = CLng(deptMins) Mod 60
.Cells(schedRow, 7).Value = TimeSerial(depH, depM, 0)
.Cells(schedRow, 7).NumberFormat = "HH:MM"

```

```

.Cells(schedRow, 8).Value = DWELL

```

```

' Alternating row shading
If schedRow Mod 2 = 0 Then
    .Cells(schedRow, 1).Resize(1, 8).Interior.Color = RGB(235, 243, 251)
End If
End With

```

```

    schedRow = schedRow + 1

```

```

Next j

```

```

    depMins = depMins + headway

```

```

    busNum = busNum + 1

```

```

Loop

```

```

NextRoute:

```

```

    Next ri

```

```

' ?? Step 6: Recalculate dependent sheets ?

```

```
Application.Calculation = xlCalculationAutomatic
```

```
Application.Calculate
```

```
Application.ScreenUpdating = True
```

```
Application.StatusBar = False
```

```
MsgBox "Done! Bus_Schedule rebuilt with " & (schedRow - 2) & " rows." &  
vbNewLine & _
```

```
    "Stop_Frequency and All_Stops_Summary have been refreshed.", _
```

```
    vbInformation, "Simulate Bus Schedule"
```

Some photos from field visit





Sample Boarding Alighting data

fid_1	6_Operat or	Std_U TM_N	Std_U TM_E	Board _Male	Bord _Femal	Aligt_ male	AligtF emal	Route_ Name	RoundTri p	Route_ Dire	Rout e_No	Std_Stop_ Nam e	Cluster Stop
116	Tarkeshw or Yatayat	30745 92.755	33163 3.2772	8	7	0	0	Jitpur Fedi- Machhapokharia RNAC	1st (Morning Peak)	Jitpur Fedi- Machhapokharia	5	Fedi Buspark Road	JitpurFedi Buspark
115	Tarkeshw or Yatayat	30745 92.755	33163 3.2772	3	4	0	0	Jitpur Fedi- Machhapokharia RNAC	1st (Morning Peak)	Jitpur Fedi- Machhapokharia	5	Fedi Buspark Road	JitpurFedi Buspark
114	Tarkeshw or Yatayat	30741 90.828	33173 5.4181	3	2	0	0	Jitpur Fedi- Machhapokharia RNAC	1st (Morning Peak)	Jitpur Fedi- Machhapokharia	5	Dakshinkali Furniture Fedi	Dakshinkali Furniture Fedi
113	Tarkeshw or Yatayat	30738 59.028	33183 9.2305	1	0	0	0	Jitpur Fedi- Machhapokharia RNAC	1st (Morning Peak)	Jitpur Fedi- Machhapokharia	5	Masalbot Tol	Jitpur fedi
112	Tarkeshw or Yatayat	30734 83.097	33212 8.7332	0	1	0	0	Jitpur Fedi- Machhapokharia RNAC	1st (Morning Peak)	Jitpur Fedi- Machhapokharia	5	Gas One Pvt. Ltd.	Gas One Pvt. Ltd.
111	Tarkeshw or Yatayat	30732 18.242	33219 2.288	1	1	0	0	Jitpur Fedi- Machhapokharia RNAC	1st (Morning Peak)	Jitpur Fedi- Machhapokharia	5	Fedi North	Fedi
110	Tarkeshw or Yatayat	30732 18.242	33219 2.288	0	3	0	0	Jitpur Fedi- Machhapokharia RNAC	1st (Morning Peak)	Jitpur Fedi- Machhapokharia	5	Fedi North	Fedi
109	Tarkeshw or Yatayat	30727 44.395	33230 2.7326	1	1	0	0	Jitpur Fedi- Machhapokharia RNAC	1st (Morning Peak)	Jitpur Fedi- Machhapokharia	5	Guinness School	Dharmasthali
108	Tarkeshw or Yatayat	30725 75.443	33220 3.0987	3	6	0	0	Jitpur Fedi- Machhapokharia RNAC	1st (Morning Peak)	Jitpur Fedi- Machhapokharia	5	Sano Bypass	Dharmasthali
98	Tarkeshw or Yatayat	30700 07.397	33247 6.1554	0	11	0	0	Jitpur Fedi- Machhapokharia RNAC	1st (Morning Peak)	Jitpur Fedi- Machhapokharia	5	Sheshmati Shanti Tole	Seshmati
97	Tarkeshw or Yatayat	30693 65.346	33266 5.9713	2	6	6	5	Jitpur Fedi- Machhapokharia RNAC	1st (Morning Peak)	Jitpur Fedi- Machhapokharia	5	Balaju Bypass	Bypass Manmaju

fid_1	6_Operat or	Std_U TM_N	Std_U TM_E	Board _Male	Bord_ Femal	Aligt_ male	AligtF emal	Route_Name	RoundTri p (Peak)	Route_Dire	Rout e_No	Std_Stop_Nam e	Cluster Stop
								RNAC		ri			Marg
96	Tarkeshw or Yatayat	30691 87.151	33264 1.6231	1	1	0	2	Jitpur Fedi- Machhapokhari- RNAC	1st (Morning Peak)	Jitpur Fedi- Machhapokha ri	5	Bypass Chowk	Machhapokha ri Bypas
95	Tarkeshw or Yatayat	30691 09.722	33288 8.3481	0	0	2	8	Jitpur Fedi- Machhapokhari- RNAC	1st (Morning Peak)	Jitpur Fedi- Machhapokha ri	5	Machhapokhari	Machhapokha ri tarkalibajar
78	Tarkeshw or Yatayat	30691 09.722	33288 8.3481	16	8	0	0	Jitpur Fedi- Machhapokhari- RNAC	1st (Morning Peak)	Machhapokhari -Jitpur Fedi	5	Machhapokhari	Machhapokha ri tarkalibajar
94	Tarkeshw or Yatayat	30693 65.346	33266 5.9713	0	2	0	0	Jitpur Fedi- Machhapokhari- RNAC	1st (Morning Peak)	Machhapokhari -Jitpur Fedi	5	Balaju Bypass	Bypass Manmaju Marg
93	Tarkeshw or Yatayat	30696 03.931	33273 8.9732	1	5	2	1	Jitpur Fedi- Machhapokhari- RNAC	1st (Morning Peak)	Machhapokhari -Jitpur Fedi	5	Nepaltar	Bypass Manmaju Marg
92	Tarkeshw or Yatayat	30698 01.115	33267 2.1802	0	1	0	2	Jitpur Fedi- Machhapokhari- RNAC	1st (Morning Peak)	Machhapokhari -Jitpur Fedi	5	Laxmisunrise Bank Nepaltar	Seshmati
91	Tarkeshw or Yatayat	30700 07.397	33247 6.1554	1	2	2	0	Jitpur Fedi- Machhapokhari- RNAC	1st (Morning Peak)	Machhapokhari -Jitpur Fedi	5	Sheshmati Naya Pul	Seshmati
90	Tarkeshw or Yatayat	30704 22.994	33254 6.7716	0	0	1	0	Jitpur Fedi- Machhapokhari- RNAC	1st (Morning Peak)	Machhapokhari -Jitpur Fedi	5	CN Mart Shesmati	Shanti Tol
89	Tarkeshw or Yatayat	30705 20.741	33260 2.6436	0	3	0	0	Jitpur Fedi- Machhapokhari- RNAC	1st (Morning Peak)	Machhapokhari -Jitpur Fedi	5	Lambagar	Shanti Tol
88	Tarkeshw or Yatayat	30706 90.957	33269 1.2615	1	1	0	2	Jitpur Fedi- Machhapokhari- RNAC	1st (Morning Peak)	Machhapokhari -Jitpur Fedi	5	Lambagar Falame Pul	Lambazar
87	Tarkeshw or Yatayat	30709 89.12	33274 3.2906	0	5	5	1	Jitpur Fedi- Machhapokhari- RNAC	1st (Morning Peak)	Machhapokhari -Jitpur Fedi	5	Shiva Mandir Gairigaun	Shiva Mandir, Jarankhu

fid_1	6_Operat or	Std_U TM_N	Std_U TM_E	Board _Male	Bord _Femal	Aligt_ male	AligtF emal	Route_Name	RoundTri p	Route_Dire	Rout e_No	Std_Stop_Nam e	Cluster Stop
86	Tarkeshw or Yatayat	30713 53.38	33264 7.3641	0	0	1	3	Jitpur Fedi- Machhapokhari- RNAC	1st (Morning Peak)	Machhapokhari -Jitpur Fedi	5	Jarakhnu Wari	Shiva Mandir, Jarankhu
85	Tarkeshw or Yatayat	30715 46.576	33262 8.6387	1	1	1	3	Jitpur Fedi- Machhapokhari- RNAC	1st (Morning Peak)	Machhapokhari -Jitpur Fedi	5	Jarankhu Bridge	Jarankhu
84	Tarkeshw or Yatayat	30723 49.545	33231 0.4767	1	0	1	10	Jitpur Fedi- Machhapokhari- RNAC	1st (Morning Peak)	Machhapokhari -Jitpur Fedi	5	Chauki	Sano Bypass
77	Tarkeshw or Yatayat	30745 92.755	33163 3.2772	3	3	0	0	Jitpur Fedi- Machhapokhari- RNAC	2nd (Day Off-Peak)	Jitpur Fedi- Machhapokha ri	5	Fedi Buspark Road	JitpurFedi Buspark
76	Tarkeshw or Yatayat	30744 81.662	33168 4.7583	0	1	0	0	Jitpur Fedi- Machhapokhari- RNAC	2nd (Day Off-Peak)	Jitpur Fedi- Machhapokha ri	5	Fedi Chowk	JitpurFedi Buspark
75	Tarkeshw or Yatayat	30741 90.828	33173 5.4181	3	0	0	0	Jitpur Fedi- Machhapokhari- RNAC	2nd (Day Off-Peak)	Jitpur Fedi- Machhapokha ri	5	Dakshinkali Furniture Fedi	Dakshinkali Furniture Fedi
74	Tarkeshw or Yatayat	30738 59.028	33183 9.2305	1	2	0	0	Jitpur Fedi- Machhapokhari- RNAC	2nd (Day Off-Peak)	Jitpur Fedi- Machhapokha ri	5	Masalbot Tol	Jitpur fedi
73	Tarkeshw or Yatayat	30734 83.097	33212 8.7332	0	1	0	0	Jitpur Fedi- Machhapokhari- RNAC	2nd (Day Off-Peak)	Jitpur Fedi- Machhapokha ri	5	Gas One Pvt. Ltd.	Gas One Pvt. Ltd.
72	Tarkeshw or Yatayat	30727 44.395	33230 2.7326	0	1	0	1	Jitpur Fedi- Machhapokhari- RNAC	2nd (Day Off-Peak)	Jitpur Fedi- Machhapokha ri	5	Guiness School	Dharmasthali
71	Tarkeshw or Yatayat	30725 75.443	33220 3.0987	1	0	0	0	Jitpur Fedi- Machhapokhari- RNAC	2nd (Day Off-Peak)	Jitpur Fedi- Machhapokha ri	5	Sano Bypass	Dharmasthali
70	Tarkeshw or Yatayat	30715 46.576	33262 8.6387	2	2	2	1	Jitpur Fedi- Machhapokhari- RNAC	2nd (Day Off-Peak)	Jitpur Fedi- Machhapokha ri	5	Jarankhu Bridge	Jarankhu
69	Tarkeshw	30709	33274	1	0	1	0	Jitpur Fedi- RNAC	2nd (Day Off-Peak)	Jitpur Fedi- RNAC	5	Shiva Mandir	Shiva Mandir,

fid_1	6_Operat or	Std_U TM_N	Std_U TM_E	Board _Male	Bord _Femal	Aligt_ male	AligtF emal	Route_Name	RoundTri p	Route_Dire	Route_No	Std_Stop_Nam e	Cluster Stop
	or Yatayat	89.12	3.2906					Machhapokhari- RNAC	Off-Peak)	Machhapokha ri		Gairigaun	Jarankhu
68	Tarkeshw or Yatayat	30709 89.12	33274 3.2906	2	3	0	0	Jitpur Fedi- Machhapokhari- RNAC	2nd (Day Off-Peak)	Jitpur Fedi- Machhapokha ri	5	Shiva Mandir Gairigaun	Shiva Mandir, Jarankhu
59	Tarkeshw or Yatayat	30693 65.346	33266 5.9713	0	1	0	0	Jitpur Fedi- Machhapokhari- RNAC	2nd (Day Off-Peak)	Machhapokhari -Jitpur Fedi	5	Balaju Bypass	Bypass Manmaju Marg
58	Tarkeshw or Yatayat	30696 03.931	33273 8.9732	0	0	0	0	Jitpur Fedi- Machhapokhari- RNAC	2nd (Day Off-Peak)	Machhapokhari -Jitpur Fedi	5	Nepaltar	Bypass Manmaju Marg
57	Tarkeshw or Yatayat	30697 39.863	33278 2.3581	0	1	1	0	Jitpur Fedi- Machhapokhari- RNAC	2nd (Day Off-Peak)	Machhapokhari -Jitpur Fedi	5	Nepaltar North	Nepaltar
56	Tarkeshw or Yatayat	30700 07.397	33247 6.1554	0	0	1	0	Jitpur Fedi- Machhapokhari- RNAC	2nd (Day Off-Peak)	Machhapokhari -Jitpur Fedi	5	Sheshmati Naya Pul	Seshmati
55	Tarkeshw or Yatayat	30711 73.347	33266 7.8495	0	0	1	1	Jitpur Fedi- Machhapokhari- RNAC	2nd (Day Off-Peak)	Machhapokhari -Jitpur Fedi	5	Nepal Ratna School Gairigaun	Shiva Mandir, Jarankhu
54	Tarkeshw or Yatayat	30713 53.38	33264 7.3641	0	0	1	2	Jitpur Fedi- Machhapokhari- RNAC	2nd (Day Off-Peak)	Machhapokhari -Jitpur Fedi	5	Jarakhnu Wari	Shiva Mandir, Jarankhu
53	Tarkeshw or Yatayat	30720 82.669	33243 2.1779	1	0	0	0	Jitpur Fedi- Machhapokhari- RNAC	2nd (Day Off-Peak)	Machhapokhari -Jitpur Fedi	5	Dharmasthali	Sano Bypass
48	Tarkeshw or Yatayat	30744 81.662	33168 4.7583	5	2	0	0	Jitpur Fedi- Machhapokhari- RNAC	3rd (Evening Peak)	Jitpur Fedi- Machhapokha ri	5	Fedi Chowk	JitpurFedi Buspark
47	Tarkeshw or Yatayat	30739 71.653	33180 5.1138	3	0	2	0	Jitpur Fedi- Machhapokhari- RNAC	3rd (Evening Peak)	Jitpur Fedi- Machhapokha ri	5	SSSB Suppliers Phedi	Jitpur fedi
46	Tarkeshw or Yatayat	30738 59.028	33183 9.2305	2	2	0	0	Jitpur Fedi- Machhapokhari- RNAC	3rd (Evening)	Jitpur Fedi- Machhapokha	5	Masalbot Tol	Jitpur fedi

fid_1	6_Operat or	Std_U TM_N	Std_U TM_E	Board _Male	Bord _Femal	Aligt_ male	AligtF emal	Route_Name	RoundTri p (Peak)	Route_Dire	Rout e_No	Std_Stop_Nam e	Cluster Stop
								RNAC	ri				
35	Tarkeshw or Yatayat	30709 89.12	33274 3.2906	0	0	0	3	Jitpur Fedi- Machhapokhari- RNAC	3rd (Evening Peak)	Jitpur Fedi- Machhapokha ri	5	Shiva Mandir Gairigaun	Shiva Mandir, Jarankhu
34	Tarkeshw or Yatayat	30706 90.957	33269 1.2615	0	0	1	1	Jitpur Fedi- Machhapokhari- RNAC	3rd (Evening Peak)	Jitpur Fedi- Machhapokha ri	5	Lambagar Falame Pul	Lamabazar
33	Tarkeshw or Yatayat	30705 20.741	33260 2.6436	0	0	0	3	Jitpur Fedi- Machhapokhari- RNAC	3rd (Evening Peak)	Jitpur Fedi- Machhapokha ri	5	Lambagar	Shanti Tol
32	Tarkeshw or Yatayat	30700 07.397	33247 6.1554	0	0	0	2	Jitpur Fedi- Machhapokhari- RNAC	3rd (Evening Peak)	Jitpur Fedi- Machhapokha ri	5	Sheshmati Naya Pul	Seshmati
31	Tarkeshw or Yatayat	30700 07.397	33247 6.1554	0	0	0	2	Jitpur Fedi- Machhapokhari- RNAC	3rd (Evening Peak)	Jitpur Fedi- Machhapokha ri	5	Sheshmati Shanti Tole	Seshmati
30	Tarkeshw or Yatayat	30698 01.115	33267 2.1802	0	0	0	1	Jitpur Fedi- Machhapokhari- RNAC	3rd (Evening Peak)	Jitpur Fedi- Machhapokha ri	5	Laxmisunrise Bank Nepaltar	Seshmati
29	Tarkeshw or Yatayat	30696 03.931	33273 8.9732	0	0	0	1	Jitpur Fedi- Machhapokhari- RNAC	3rd (Evening Peak)	Jitpur Fedi- Machhapokha ri	5	Nepaltar	Bypass Manmaju Marg
17	Tarkeshw or Yatayat	30715 46.576	33262 8.6387	2	1	1	2	Jitpur Fedi- Machhapokhari- RNAC	3rd (Evening Peak)	Machhapokhari -Jitpur Fedi	5	Jarankhu Bridge	Jarankhu
16	Tarkeshw or Yatayat	30719 60.16	33259 6.298	0	0	3	1	Jitpur Fedi- Machhapokhari- RNAC	3rd (Evening Peak)	Machhapokhari -Jitpur Fedi	5	Sk Hardware Jharankhu	Sano Bypass
15	Tarkeshw or Yatayat	30719 60.16	33259 6.298	2	2	0	2	Jitpur Fedi- Machhapokhari- RNAC	3rd (Evening Peak)	Machhapokhari -Jitpur Fedi	5	Sk Hardware Jharankhu	Sano Bypass
3	Tarkeshw or Yatayat	30743 26.148	33168 7.0316	0	0	0	2	Jitpur Fedi- Machhapokhari- RNAC	3rd (Evening Peak)	Machhapokhari -Jitpur Fedi	5	Fedi Aggricultural Farm	Dakshinkali Furniture Fedi

fid_1	6_Operator	Std_U TM_N	Std_U TM_E	Board _Male	Bord_Board Femal	Alight_Board male	AlightFemal	Route_Name	RoundTrip	Route_Direction	Route_No	Std_Stop_Name	Cluster Stop
2	Tarkeshw or Yatayat	30739 51.606	33005 8.0422	0	0	2	0	Jitpur Fedi- Machhapokhari- RNAC	3rd (Evening Peak)	Machhapokhari -Jitpur Fedi	5	Jitpurfedi 1	Jitpurfedi 1
1	Tarkeshw or Yatayat	30691 09.722	33288 8.3481	0	0	4	6	Jitpur Fedi- Machhapokhari- RNAC	3rd (Evening Peak)	Machhapokhari -Jitpur Fedi	5	Machhapokhari	Machhapokha ri tarkalibajar