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# Evaluating Public Transport Accessibility for Work, Education and Health Trips: A Case Study of Kathmandu Valley

**by**

**Sajan Pandey**

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The undersigned certify that they have read and recommended to Institute of Engineering for acceptance, a thesis entitled **"Evaluating Public Transport Accessibility for Work, Education and Health Trips: A Case Study of Kathmandu Valley"** submitted by Sajan Pandey in partial fulfillment of the requirement for degree of Master of Science in Transportation Engineering.

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# ABSTRACT

Kathmandu Valley is witnessing increased transportation system challenges, including congestion, traffic crashes, pollution, and inequities in public transport access. Despite an increase in trips, public transport remains unstructured, inefficient and unreliable services, which has further led to increase private vehicle ownership. In this context, evaluating public transport accessibility is crucial to identify service gaps, guide infrastructure investments, and ensure equitable mobility for all population groups. This study evaluates public transport accessibility and its equity implications by assessing accessibility scores at the ward level of municipalities in Kathmandu Valley based on work, education, and health Points of Interest (POIs). Using Geographic Information Systems (GIS), General Transit Feed Specification (GTFS) data, and PTV Visum, a comprehensive travel time analysis was conducted. Travel times were clustered using the CLARA (Clustering Large Applications) method to define accessibility categories, and the Public Transport and Walking Accessibility Index (PTWAI) was used to quantify accessibility levels across 247 wards in Kathmandu Valley. Additionally, accessibility scores were compared with wealth quintile data from the National Population and Housing Census (2021) to identify underserved populations and assess equity in transport access. The numerical analysis shows wards of Kathmandu Metropolitan and Lalitpur Metropolitan have the highest average work, education and health accessibility and the wards of Konjyosom, Bagmati, Mahankal and Shankharapur exhibit low accessibilities using public transportation. The study provides insights into areas requiring investment to improve public transport equity and sustainability. By enhancing public transport, Kathmandu Valley can mitigate its dependency on private vehicles and promote inclusive urban mobility.

**Keywords:** GIS, GTFS, PTWAI, Public Transport Accessibility, Transport Equity, Travel Time Clustering,

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# LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| ADB | : | Asian Development Bank |
| CBS | : | Central Bureau of Statistics |
| CLARA | : | Clustering Large Applications |
| DOTM | : | Department of Transport Management |
| EMIS | : | Education Management Information System |
| FCCPTA | : | Federal Capital City Public Transport Authority |
| GIS | : | Geographic Information Systems |
| GTFS | : | General Transit Feed Specification |
| HIB | : | Health Insurance Board |
| JICA | : | Japan International Cooperation Agency |
| KSUTP | : | Kathmandu Sustainable Urban Transport Project |
| LOS | : | Level of Service |
| MoHP | : | Ministry of Health and Population |
| O-D | : | Origin-Destination |
| OSM | : | Open Street Map |
| PA | : | Potential Accessibility |
| PAM | : | Partitioning Around Medoids |
| PHCs | : | Primary Health Centers |
| PJT | : | Perceived Journey Time |
| POIs | : | Points of Interests |
| PTAL | : | Public Transport Accessibility Level |
| PTWAI | : | Public Transport and Walking Accessibility Index |
| SAL | : | Structural Accessibility Level |
| SI | : | Supply Index |
| SUEP | : | Sustainable E-Mobility Project |
| UNCRD | : | United Nations Centre for Regional Development |
| UGC | : | University Grants Commission |

# CHAPTER 1: INTRODUCTION

## 1.1 Background

Accessibility, as defined by Litman (2008), refers to the ease with which people can reach services and opportunities, ideally reducing the need for travel by ensuring that essential facilities are within proximity. Accessibility can also be considered as the ease with which activities at one place may be reached from another via a particular travel model (Liu & Zhu, 2003). Access to public transport is crucial for sustainable urban mobility. It influences employment opportunities and economic participation and is a key component of integrated transport planning (Langford et al., 2012). Increased transport activities, without systematic planning, exacerbate urban congestion and environmental degradation, underscoring the urgent need for well-planned, accessible public transport systems (Prajapati et al., 2020).

Globally, studies have shown that enhancing public transport accessibility is critical for sustainable urban mobility. Increasing accessibility to public services is a crucial area of transport policy and urban planning as well as being a key foundation of an integrated transport system (Wu & Hine, 2003). Poor public transport accessibility to education, jobs and health facilities and inequity in transport provision can have a large impact on vulnerable people within a society (Langford et al., 2012). In South Asian contexts, however, high-density populations, informal settlements, and limited road space often challenge urban mobility. Research by Pojani (2015) emphasizes that inclusive, affordable, and accessible public transport systems are vital to managing congestion and enhancing urban livability. Kathmandu Valley, with its rapidly expanding urban footprint, exemplifies these challenges, highlighting the need for effective public transport planning to improve accessibility for all socioeconomic groups.

Addressing public transport accessibility in Kathmandu Valley aligns with sustainable transport objectives (UNCRD, 2015), aiming to create a system that is environmentally friendly, socially inclusive, and economically feasible. This study seeks to assess the current accessibility and coverage of public transport, identifying areas with low accessibilities in various domains (work, health and education), providing insights for planning purposes while reducing Kathmandu Valley's over-reliance on private vehicles.

## 1.2 Statement of the Problem

Kathmandu Valley, one of the South Asia's fastest-growing urban areas with a growth rate of 6.5% per year (Timsina,2020), faces severe transportation challenges due to rapid population growth and diverse land use resulting in rising vehicle numbers, traffic congestion, pollution, and crashes. Bagmati Province's transportation landscape is marked by rapid motorization, with a vehicle fleet heavily dominated by motorbikes, comprising 79.1% of the total, followed by private vehicles (12.42%), heavy-duty vehicles (4%), and public transport vehicles at just 2.67% (DOTM, 2018). This skewed distribution indicates an over-reliance on private modes of transportation and suggests limited public transport usage, contributing to congestion, air pollution, and other urban mobility challenges. The annual vehicle growth rate in Bagmati Province has reached 14%, placing further pressure on the valley's road infrastructure and raising sustainability concerns.

The understanding of public transport accessibility gives the insight to transport planners on the area needing investment for planning. A large body of research has been conducted measuring accessibility, but there is limited research on quantifying public transport accessibility in the informal and unscheduled transport system, prevailed in most of the developing countries like Nepal (Prajapati et al., 2020). There is a lack of comprehensive understanding regarding accessibility disparities across the valley's wards, especially concerning access to essential work, education and health points of interest (POIs). Since maximum trip purposes by bus is towards education and work trips as per JICA (2012) report, so by calculating the accessibility scores of the wards by means of public transport, planning can be done on where improvements are to be done. This study seeks to address these gaps by analyzing the accessibility score of wards based on work, education and health POIs, assessing public transportation coverage to identify underserved populations, and comparing equity performance across wards using accessibility scores alongside the Wealth quintiles. By making public transport accessible, cities can reduce reliance on private vehicles and promoting efficient urban mobility.

## 1.3 Research Objectives

The main objective of the study is to determine public transport accessibility to work, education and health domains by use of public transport. The specific objectives are enlisted as below:

1) To establish a public transport accessibility scoring for Kathmandu valley based on public transport travel time ranges.
2) To determine the percentage of population in each accessibility ranges based on accessibility scores for work, education and health domains.
3) To calculate equity in accessibility among wards and compare accessibility scores with wealth quintiles of wards.

## 1.4 Scope of Study

The study's intended scope is as follows:

1) Establishing a public transport accessibility scoring system based on travel time to work, education, and health facilities by clustering the travel time data using the K-medoids algorithm.
2) Determining the percentage of the population with inadequate access to key point of interests using public transport based on accessibility scores.
3) Use of Lorenz Curve and Gini coefficient to compare equity of accessibility to work, education and health domains using public transport in Kathmandu Valley.

## 1.5 Limitations

The thesis report is prepared under the following limitations:

1) The origin of the trips and the point of interest in the work domain is taken as ward's geometric centroids instead of settlement and work locations.
2) Wards are taken as the smallest unit for measurement of accessibility.
3) Detailed pedestrian network data such as sidewalk availability, pedestrian safety, and walkability constraints are not considered.

4) It has been assumed that all the population in a ward will be considered in the calculation of underserved populations without considering their mode choices.
5) Work, Health and Education domains, which are among the major home-based trips are only considered.
6) Only higher education offering institutions in education domain and service providing hospitals by health insurance board in health domain are considered.

### 1.6 Organization of Report

The chapters of the report are organized as follows:

Chapter 1: Introduction: It deals with background of study, problem statement, objectives of research, scope of study and limitations of the study.

Chapter 2: Literature Review: It deals with literature background on various topics such as set covering problems, clustering algorithms, analytical hierarchy process, multi-criteria decision analysis etc.

Chapter 3: Methodology: It deals with methods of clustering, analytical hierarchy process, data collection, multi-criteria decision analysis, and maximal covering problem that are being used in this study.

Chapter 4: Results and Discussion: This chapter deals with analysis of various results of the methodology applied as mentioned in chapter 3.

Chapter 5: Conclusion and Recommendations: This portion provides the final conclusion and works remaining in the study.

# CHAPTER 2: LITERATURE REVIEW

## 2.1 Methods of Measuring Accessibility

Accessibility has wide range of dimensions, includes, spatial separation (i.e. travel time, travel cost, information, reliability), origins (locations, person), destination (job, people, services, facilities), geographical scale (like regional scale), travel modes (public, private), route choice, time of day, environmental impact, and topographic features.

Existing studies have various understandings and definitions of accessibility, which result in different ways of calculation and modeling. Hansen created the concept of accessibility on transportation as the size of interaction opportunities of nodes in traffic networks, and the Hansen Gravity Model was established in the process of distributing the forecasted metropolitan population to small areas within the metropolitan region (Hansen, 1959). Other measures like minimum travel time and the shortest travel distance (R & Huzayyin, 1979), the difficulty for the OD points to overcome the space separation contact(Ingram, 1971) and the number of opportunities that can be obtained in the range of unit time or unit distance (Wachs & Kumagai, 1973) have been mostly used as well. However in recent times, the number and diversity of destinations that travelers can reach (Bertolini et al., 2005), and the potentials of interaction or contact between OD points (Grengs, 2014) are used. Existing accessibility measures can be categorized into three main groups, including access to public transport stops, duration of a journey by public transport and access to a destination via public transport modes (Mavoa et al., 2012). In recent researches, the accessibility score is given based on different approaches like Public Transport Accessibility Level (PTAL) and Supply Index (SI) have been used. The PTAL uses the Waiting time, service waiting time and total access time and groups the accessibility index into 0(worst) to 6b(best) (Currie, 2010). The Supply index incorporates population density to accessibility calculations. The researchers introduce a modified gravity-based measure that accounts for service frequency, travel time to key destinations, waiting and transfer times, socioeconomic factors (Saghapour et al., 2016). The Structural Accessibility Level (SAL) includes the land-use and transport components, but not the temporal and individual components (Silva, 2008). It includes two accessibility measures, the diversity of activity index (DivAct) and a comparative accessibility measure (accessibility cluster) for categorization. In a comparative study conducted in Helsinki, researchers evaluated two location-based methods for assessing public transport accessibility: the Structural Accessibility Layer (SAL) and the PTWAI (Albacete et al., 2015).

In context of Nepal, about 56% of Kathmandu has convenient access to public transportation i.e. access to bus stop which was measured as the share of the population within 500 meters walking distance of low capacity transport systems (buses and trams) and 1,000 meters distance to high-capacity systems (trains, subways and ferries) (ATO, 2023). Also, the analysis of the current scenario regarding access to transport services for person with disability (PWD) in Kathmandu Valley was done by surveying people with disabilities in Kathmandu about mobility needs and problems faced regarding transportation in Kathmandu (Bhusan,2019). A model for travel time reliability of public bus transport of Airport to Narayan Gopal Chowk by conducting onboard surveys was done to identify the major delays (Kumar Thapa et al., 2024). In another research, accessibility index and total access time was measured by consolidating the walk time from the POI to the point for which the PTAL was being determined for Kalanki- Bhotahity section (Anjay Kumar Mishra et al., 2020).

## 2.2 Public Transport and Walking Accessibility Index (PTWAI) Approach

The PTWAI is a measure used by Mavoa et al. (2012) to calculate accessibility for public transport and walking in New Zealand. All land parcels within the service areas were assigned an accessibility score from 0 to 4, based on the travel times shown in Table 2.1. A score of 0 indicates a travel time exceeding 60 min travel by transit and on foot along the road network to get to the destination. A score of 4 represents high accessibility and means that the destination is accessible within 10 min transit and walking travel.

Averaged domain accessibility was calculated prior to calculating the PTWAI to ensure that each domain has equal weighting in the final index. The PTWAI for each parcel is a value ranging from 0 to 20 (for five domains i.e. education, health, shopping, financial and social).

PTWAI has been used in urban planning to identify low-accessibility zones and guide strategic transport investments. Given the informal and unscheduled nature of public transport in Kathmandu Valley, adopting a PTWAI-based accessibility approach can provide crucial insights for addressing mobility gaps and ensuring equitable access for public transport trips.

Table 2.1 : Accessibility Scores Assigned for Alternate Travel Time Scenarios

| Accessibility Score | Threshold Times Extracted from Mavoa et al.(2012) (minutes) |
|---|---|
| 0 | >60 |
| 1 | 40-60 |
| 2 | 20-40 |
| 3 | 10-20 |
| 4 | 0-10 |

## 2.3 Clustering Approaches

Clustering techniques play a significant role in transportation analysis by grouping similar data points to extract meaningful insights. These methods are widely applied in traffic flow analysis, travel time estimation, public transport accessibility studies, and mobility pattern recognition. Among various clustering techniques, K-Medoids and CLARA (Clustering Large Applications) are particularly notable for their robustness in handling real-world transportation datasets.

K-Medoids, an alternative to K-Means, is a partitioning-based clustering algorithm that selects actual data points (medoids) as cluster centers, making it less sensitive to outliers and more suitable for transportation data characterized by non-Euclidean distances and noise. Several studies have utilized K-Medoids in transportation research. For instance, Bhuyan and Rao (2012) applied K-Medoids to classify urban street segments based on Level of Service (LOS) criteria using GPS-based speed data. Their findings demonstrated that K-Medoids effectively grouped road segments with similar speed characteristics, aiding in urban mobility planning. Similarly, in public transport research, K-Medoids has been used to cluster bus stops and route segments based on accessibility and demand characteristics, helping policymakers optimize transit networks.

While K-Medoids is effective, its computational complexity (O(n^2)) makes it impractical for large-scale datasets. To address this, the CLARA algorithm was introduced by Kaufman and Rousseeuw (1990) as a scalable variant of K-Medoids. CLARA reduces computational burden by selecting representative subsets of the data and applying K-Medoids within each sample. Studies leveraging CLARA in transportation include Das and Bhuyan (2014), who employed it to define urban street LOS criteria based on GPS-derived speed profiles. The algorithm enabled efficient classification of street segments, even in large datasets, demonstrating its utility in big-data transportation studies.

Another significant application of CLARA is in travel time pattern analysis. Shaji et al. (2022) integrated CLARA with predictive models to enhance travel time forecasting accuracy. By clustering historical travel time data, the study improved the reliability of real-time traffic estimations, highlighting CLARA's effectiveness in dynamic transportation environments. Moreover, CLARA has been applied to analyze public transport accessibility by clustering city zones based on proximity to transit stops, thus facilitating equitable transport planning.

## 2.4 Visum in Public Transportation Analysis

PTV Visum is a widely used transport planning software that enables comprehensive analysis of public transportation networks, including accessibility assessment, demand modeling, and service optimization. Several studies have used Visum's capabilities to assess and improve public transport efficiency. Visum was used to optimize transit routes, reducing travel times and operational costs (Heyken Soares et al., 2020). Multimodal networks were integrated in Visum for improved analysis (Friedrich et al., 1999). Visum was employed to evaluate and enhance the public transportation system of Denizli, Turkey, using a Potential Accessibility (PA) measure as a key metric to assess network efficiency and identify areas requiring service improvements (Gulhan et al., 2014). Visum provides three assignment methods for public transportation;transport system-based procedure, headway-based procedure, timetable-based procedure. The headway-based procedure is ideal for urban networks with short headways and for long-term conceptual planning, as long as the timetable for the period being analyzed is still unknown. The headway based procedure determines the transfer wait time at transfer stops from the mean headway of the succeeding lines. Doing without the timetable on the level of individual trips ensures short computing times even for large networks. In the context of Kathmandu Valley, where public transport is often fragmented and operates without fixed timetables, the headway-based assignment method in Visum becomes especially valuable. This approach does not require predefined schedules or detailed timetables, making it suitable for areas with informal, unscheduled transport systems, which are common in Kathmandu.

## 2.5 Accessibility and Equity

Equity means an equal and fair distribution of resources, services, benefits, and costs among individuals, stakeholders, and society. There are various viewpoints about transportation equity; however, a standard and uniform definition has not yet been presented for it (Pereira et al., 2016). Transportation equity is the prerequisite for social inclusion and reducing social discrimination (Jones & Lucas, 2012). There are pieces of evidence that indicate that sometimes there are inequities concerning transportation systems. In some cities, specific groups such as those with disabilities, low-income groups, women, old people, socially disadvantaged people, students, and children confront some sort of inequity in relation to transportation accessibility (Caggiani et al., 2017). Qi et al. (2019) tried to determine public transportation equity based on the relative accessibility to CBD, public transportation needs, and population density. Ghosh et al. (2022) assessed equity for public transportation in India based on an accessibility index. Generally, transport disadvantage has a strong relationship with social exclusion. If transport-disadvantaged residents have no chance to increase access to destinations, their social exclusion will intensify (Garrett and Taylor 1999).

## 2.6 Summary of Literature Review

The literature review highlights various methods for measuring accessibility, including spatial separation, travel time, cost, and destination opportunities. Several accessibility measures, such as the Hansen Gravity Model, PTAL, and Supply Index (SI), have been widely used in accessibility research. The PTWAI approach, which combines public transport and walking accessibility, has been applied to identify mobility gaps and guide transport planning. In context of Nepal, studies highlight that while over half of Kathmandu's population has convenient access to public transport; significant gaps remain, especially for persons with disabilities and in terms of service reliability and total access time—indicating a need for more inclusive and efficient public transport planning. Clustering techniques like K-Medoids and CLARA have been effectively utilized in transportation studies to classify urban segments based on accessibility and demand.

Additionally, transport planning tools like PTV Visum offer analytical methods for public transport assessment and optimization, particularly using the headway-based assignment method for informal and unscheduled transit systems.

Despite extensive research on accessibility, existing studies largely focus on structured, scheduled transport networks, making them less applicable to Kathmandu Valley's informal and fragmented transit system. There is a lack of studies that quantify public transport accessibility using empirical methods in Kathmandu's unique transport landscape, where unscheduled transit services dominate. This research aims to bridge this gap by developing an accessibility scoring system based on travel time clustering, identifying underserved populations, and evaluating equity in transport access across wards. By integrating PTWAI and clustering techniques, this study will provide a comprehensive understanding of public transport accessibility and highlight areas requiring targeted interventions to improve urban mobility in Kathmandu Valley.

# CHAPTER 3: METHODOLOGY

## 3.1 Research Design

The research is guided according to the steps shown in Figure 3.1. The flowchart outlines a methodology for assessing public transport accessibility and equity in Kathmandu Valley. It begins by defining the study area, followed by data collection, which includes on board surveys for gathering information on public transport routes, their frequencies, and time stamps for reaching stops. The collected data is then mapped into a GIS framework, the stops of multiple routes are clustered within a radius of 50m by DBSCAN to identify same stops and GTFS files are created using Python to structure the transit data. Using PTV Visum, the model incorporates ward centroids as origins, key points of interest (POIs) as destinations and the generated GTFS files to estimate travel times. The travel times are first plotted in an elbow plot, which is a curve of inertia vs number of clusters to get the ideal number of clusters. These travel times are then clustered into the obtained number of ranges using the k-medoids clustering method. This study aims to calculate a weighed accessibility value for measuring the level of work, education and health accessibility to public transport in Kathmandu valley's 247 wards, the smallest administrative unit served as basic units of analysis where population data are aggregated to its centroid. The accessibility of each ward is then calculated using clustered time ranges obtained from k medoids clustering and weighting the scores of each ward to reflect demand distribution. The scores are separated into ranges and integrated census data to identify underserved populations in each domain. The accessibility results are then compared with the Wealth Quintiles from CBS (2021) to analyze disparities in accessibility and equity. This process helps in evaluating the inclusiveness and efficiency of public transportation in the study area.

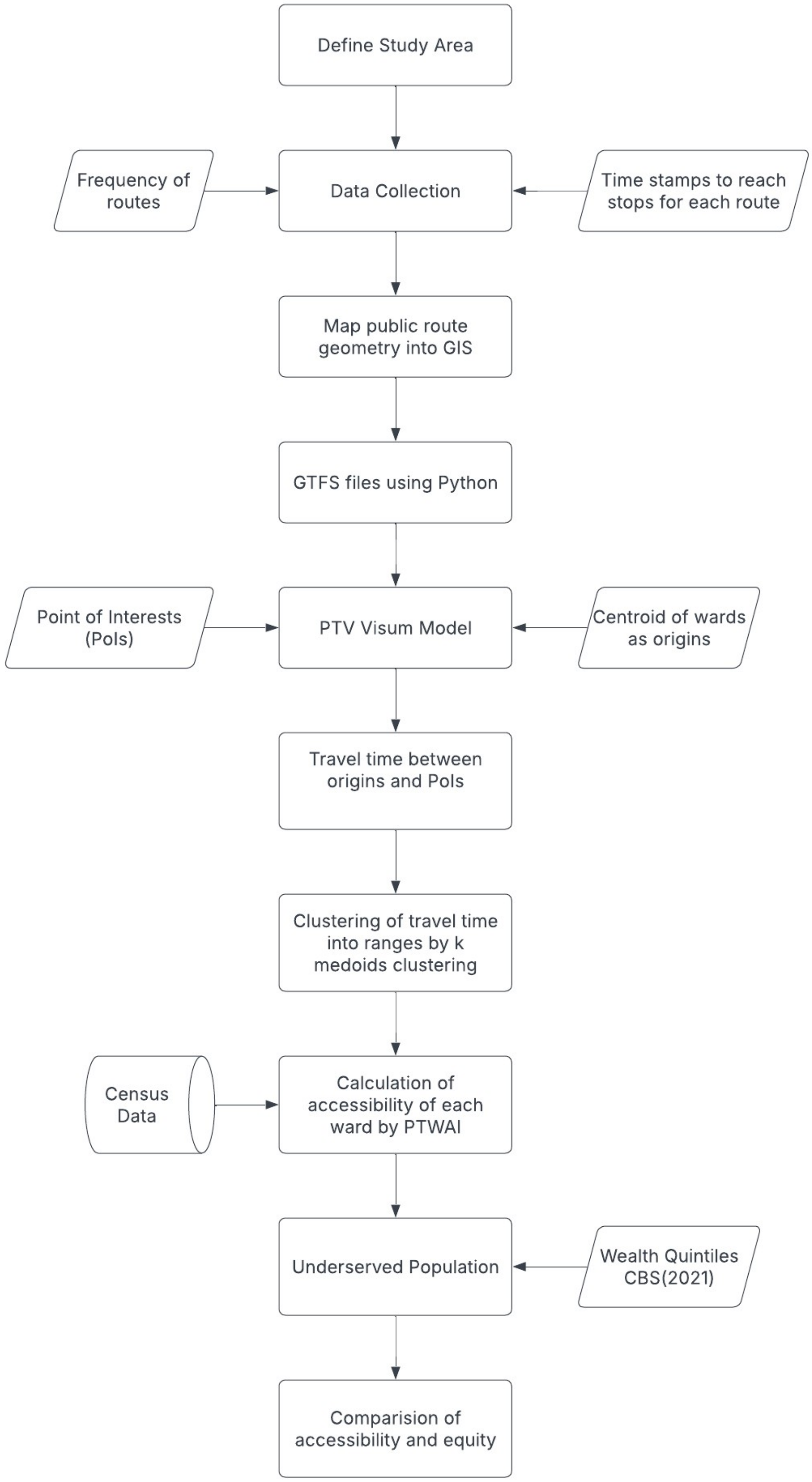


Figure 3.1: Research Design

### 3.2 Study Area

The study area encompasses the three central districts of Kathmandu Valley as shown in Figure 3.2. These districts form the urban core of Nepal, with a high population density, extensive economic activity, and significant transportation challenges. The smallest administrative unit used for analysis will be the ward, allowing for spatial understanding within each district. Each ward's geometric center will serve as the origin and destination points for trips, enabling a systematic and standardized approach to modeling accessibility and travel patterns.

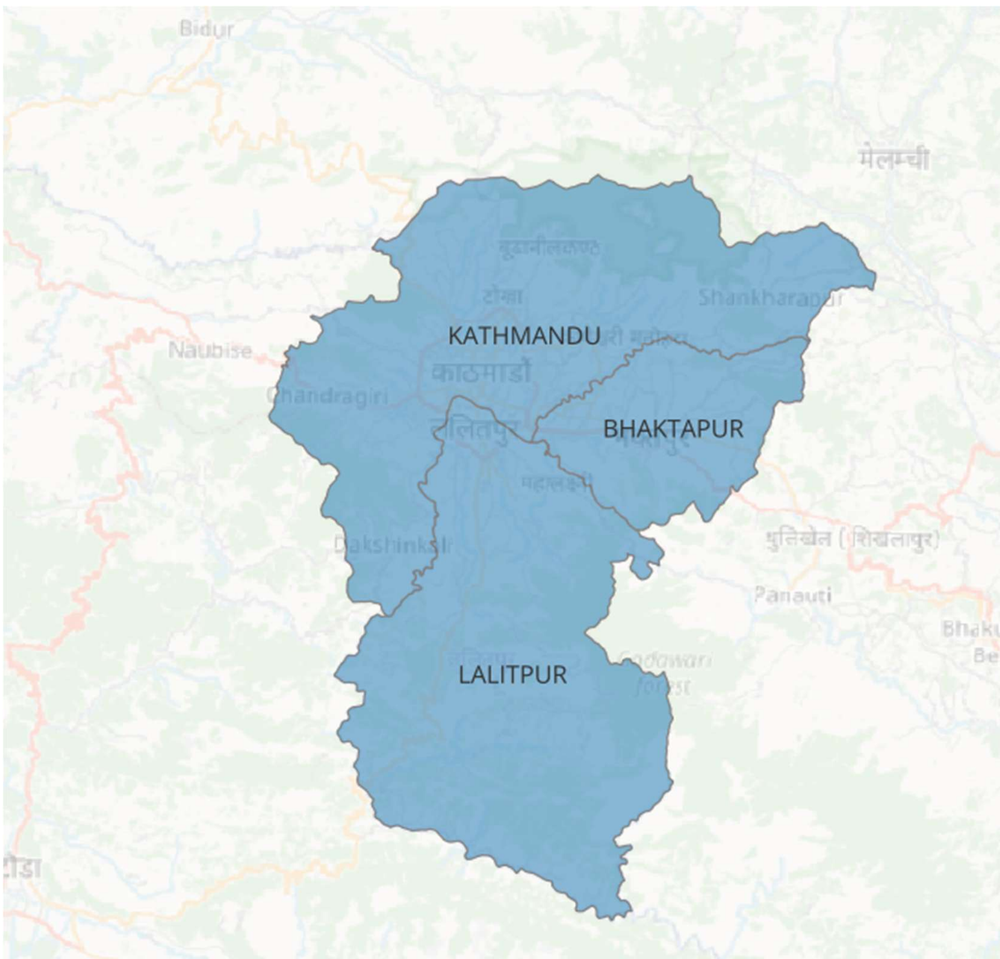


Figure 3.2: Study Area

## 3.3 Data Collection

There is currently no structured database for the route permit system maintained by government agencies in Nepal. Furthermore, a significant number of routes are operated by various operators in an uncoordinated and fragmented manner. The Public Transport Restructuring Project supported by the ADB (MoPIT,2014), as part of the Kathmandu Sustainable Urban Transport Project (KSUTP), mentions operation of around 200 routes, many of which overlapped, and recommended a restructuring of the routes. A more recent study by FCCPTA in 2024 listed 132 public transport routes in the Valley, based on inquiries with operators and transportation associations (FCCPTA, 2024). Furthermore, Transport Office in Ekantakuna is working to digitalize the route information and reports the existence of approximately 72 bus and minibus routes along with 15 microbus and tempo routes. Although some regional routes passes through the southern part of the valley there are limited routes connecting these parts of the valley to the core.

This study uses the route information collected by a study conducted by Asian Development Bank (ADB) in collaboration with Ministry of Physical Infrastructure and Transport, a total of 133 onboard surveys were conducted in September – October 2024, during peak hours of work days excluding Fridays after 2 PM to ensure data uniformity. The surveys were conducted in both directions in which stop locations and the timestamps for arrival and departure at each stop were recorded. The public transport routes surveyed are shown in Figure 3.3. The headways were manually collected at the terminals by interviewing the drivers, conductors and by waiting for the next departure.

Additionally, the secondary data of census collected from National Population and Housing Census, point of interests information through websites, locations from Google maps and public transport route data from concerned authorities. The city base map is taken with the plugin QuickOSM from QGIS for the study area. The boundary information is obtained from the Department of Survey, Government of Nepal. The proportion of population within the poorest and poorer (lower two quintiles) based on the national average as classified by the wealth quintiles in the National Population and Housing Census (2021) is used to express the disparity in wealth of the population of wards.

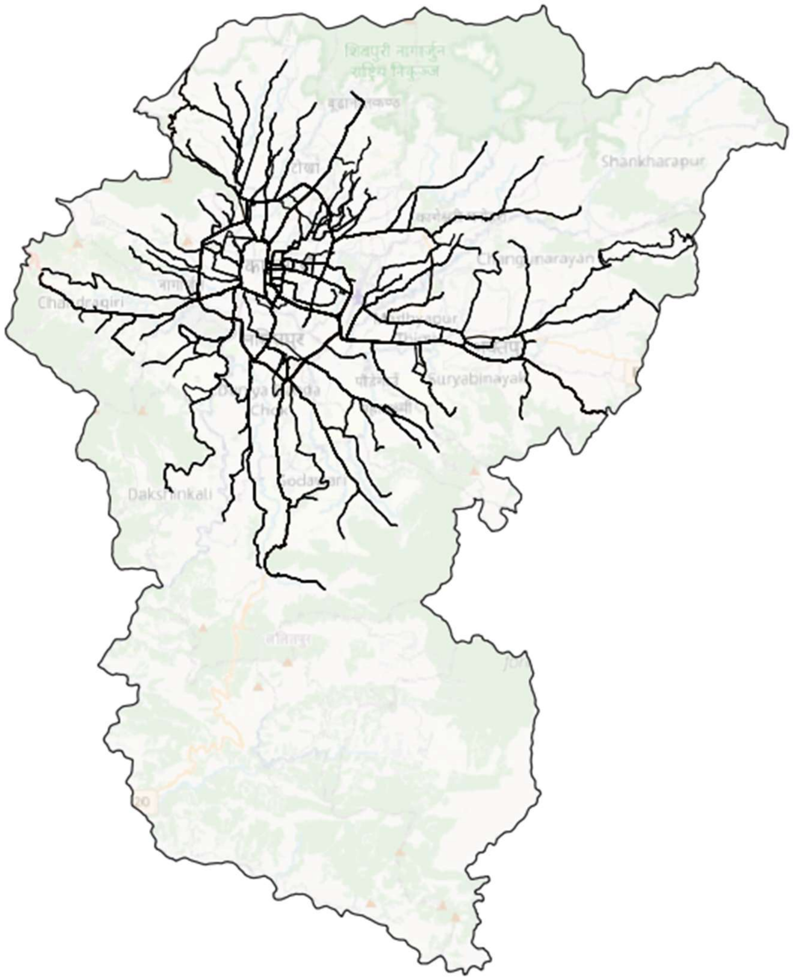


Figure 3.3: Public Transport Routes Operating within Kathmandu Valley

### 3.4 Point of Interests (POIs)

According to JICA (2012), data collection survey report on Kathmandu Valley, the trip purpose by bus was highest for to school, to work trips and other trips. So, the POIs for this research was based on Work, Education and Health Domains.

#### 3.4.1 Work Domain

In the work domain, the centroid of each ward served as the representative location for work-related accessibility analysis. The data required for this analysis came from the National Economic Census 2018, published by the National Planning Commission and the

Central Bureau of Statistics (CBS). This report contains number of establishments and persons engaged in the establishments by sex at ward level of each local administrative level. The accessibility scores were weighted by the number of people working in each respective ward to better represent work-related accessibility. By incorporating workforce distribution into accessibility scoring, this approach provides a realistic measure of how well different areas within Kathmandu Valley are connected to job opportunities.

### 3.4.2 Education Domain

For the education domain under Points of Interest (POIs), the accessibility analysis was based on data from the Education Management Information System (EMIS) report for the fiscal year B.S. 2080/081 (2023/24 A.D.), published by the University Grants Commission (UGC), Nepal. This report provided comprehensive statistical data on higher education institutions across the country, including Central and Provincial Universities, Medical Academies, and their constituent and affiliated campuses, covering both community and private institutions.

For the study, colleges identified in the EMIS report with a student population of more than 100 was considered as POIs for the education domain. These 288 colleges served as key destinations for accessibility assessment. To ensure a more representative measure of educational accessibility, the computed accessibility scores was weighted by the number of students enrolled in each college. This weighting accounts for variations in student concentration across different educational institutions, ensuring that colleges with larger student populations have a greater impact on the final accessibility evaluation.

### 3.4.3 Health Domain

Under the health domain for Points of Interest (POIs), the accessibility analysis was based on the 55 service providing hospitals listed by the Health Insurance Board (HIB). Health Insurance Board (HIB) is a social protection program of the Government of Nepal that aims to enable its citizens to access quality health care services without placing a financial burden on them. This program attempts to address barriers in health service utilization and ensure equity and access of poor and disadvantaged groups as a means to achieve Universal Health Coverage. The primary health centers (PHCs) were provided a weightage of 1, the hospitals with less than 75 beds were provided a weightage of 2 and the central hospitals and disease-specific hospitals as listed by the Ministry of Health and Population (MoHP) were provided a weightage of 5. These hospitals serve as key healthcare facilities providing specialized and general medical services. The official list of these central hospitals is available on the MoHP website, ensuring that only recognized and significant healthcare institutions were weighted highly for accessibility evaluation. This weighting accounts for variations in patients concentration across different health institutions, ensuring that hospitals with larger patients and better services have a greater impact on the final accessibility evaluation.

Figure 3.4 represents the Points of Interests (PoI) of different domains across the valley.

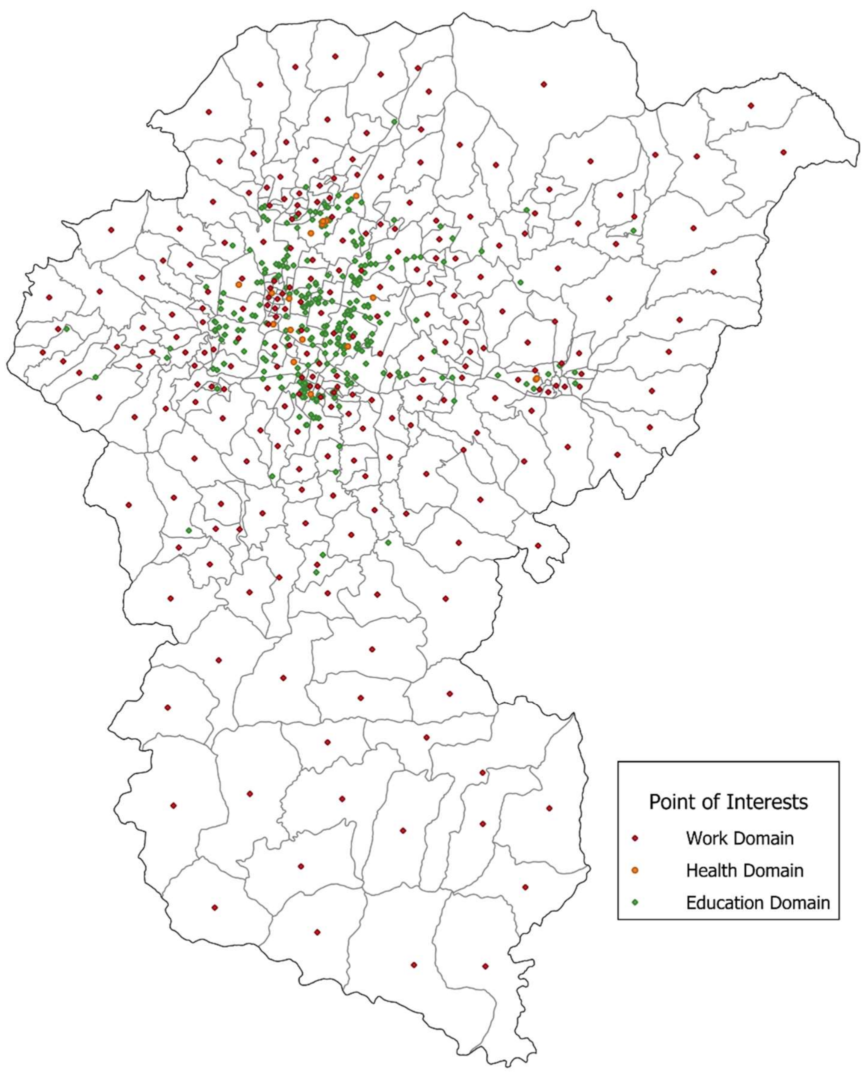


Figure 3.4: Point of Interests across the Valley in Different Domains

## 3.5 Calculation of Travel Times

The shape files from the onboard boarding and alighting survey and the frequency data were processed by python code and converted into GTFS format. The GTFS feed, boundary information, city base map were supplied to PTV Visum. A 247 × 247 travel time matrix is developed (zone to zone) to capture travel times between each OD pair based on minimum impedance, which is the perceived journey time.

The Perceived Journey Time (PJT) for each Origin-Destination (OD) pair is computed in VISUM as illustrated in Equation 3.1.

$$\mathbf{PJT} = \text{In vehicle time} + \text{Access time} + \text{Egress time} + \text{Transfer walk time} + \text{Origin wait time} + \text{Transfer wait time} \quad (3.1)$$

The waiting time is the average time between arriving at a stop and the arrival time of public transport. For each selected route, the waiting time was considered as the interval between services. If the frequency is 6 vehicles/hr., the headway is 10 minutes/vehicle and the wait time will be 5 minutes. The calculation of wait time is done as per Equation 3.2.

$$Wait\ time_{ij} = 0.5 \times \frac{60}{Frequency_{ij}} \quad (3.2)$$

The access and egress times are determined using the shortest path computed via Dijkstra's algorithm. The OSM road network is imported in python via geopandas and a NetworkX graph is created from the road network. Walk distances were converted to a measure of time assuming an average walk speed of 1.2m/s (Bishnu, 2014).

## 3.6 Clustering of Travel Times by K Medoids (CLARA)

The travel time ranges presented in Table 2.1 are based on data from New Zealand (Mavoa et al., 2012). However, these ranges may not be directly applicable to a geographically and economically distinct region such as the Kathmandu Valley, where public transport systems and their coverage differ significantly. Therefore, clustering analysis has been used to classify travel time ranges more appropriately.

Clustering analysis is an unsupervised machine learning technique used to group data points based on similarity. Several clustering methods exist, including K-Means, K-Medoids, DBSCAN, and Hierarchical Clustering (Qing Li, 2022). This report specifically employs the K-Medoids clustering technique, a partitioning-based algorithm that minimizes the sum of dissimilarities between data points and their most representative counterparts (medoids) within a cluster. Comparative studies of K-Means and K-Medoids on large datasets suggest that K-Medoids performs better in terms of cluster head selection time and space complexity when dealing with overlapping clusters. Additionally, K-Medoids offers advantages over K-Means in execution time, robustness to outliers, and noise reduction, as it minimizes the total dissimilarity among data points (Arora et al., 2016). CLARA (Clustering Large Applications) is an extension of the K-Medoids algorithm designed for large datasets. The original K-Medoids (PAM) algorithm has a high computational cost, making it inefficient for large datasets. CLARA was introduced by Kaufman & Rousseeuw (1990) to address this scalability issue. CLARA selects multiple random samples (subsets) of data points to compute medoids. The best medoid set is chosen based on the lowest clustering cost.The Euclidean distance (dissimilarity distance) between medoid and data point can be represented in Equation 3.3.

$$d(x_i, m_j) = \sqrt{\left(\sum_{k=1}^{n} (x_{ik} - m_{jk})^2\right)} \tag{3.3}$$

Where,

$d(x_i, C_j)$ : $Euclidean\ distance\ between\ data\ point\ (\ x_i)\ and\ medoid\ (\ m_j)$

$x_i$ : $Data\ point\ (\ i\ )$

$m_j$ : $Medoid\ (\ j\ )$

$x_{ik}$ : $Value\ of\ the\ k^{th}\ feature\ of\ data\ point\ (\ i\ )$

$m_{jk}$ : $Value\ of\ the\ k^{th}\ feature\ of\ medoid\ (j)$

As there are travel time data from 247 zones to large number of point of interests, the travel time data is very large and contains outliers with large values as well due to walking distances where public transport coverage is not proper, so k medoids (CLARA) clustering is adopted.

### 3.7 Elbow Plot and Silhouette Scores

The inertia calculated by Equation 3.4 assuming trial values of clusters and then is plotted against the number of clusters to get an elbow plot. In the elbow plot the elbow point i.e. when the slope of the graph changes from steep to flat is considered as the optimum number of clusters.

$$Inertia = \sum_{i=0}^{n} d(x_i, m_j) \tag{3.4}$$

The Silhouette score is a metric used to evaluate how good clustering results are in data clustering. This score is calculated by measuring each data point's similarity to the cluster it belongs to and how different it is from other clusters. The Silhouette score is commonly used to assess the performance of clustering algorithms like K-Means and medoids.

For each data point, the average distance $a(i)$ to other data points within the same cluster is calculated. This value represents the similarity level of the data point to others in its cluster. Then, the average distance $b(i)$ to all other clusters it doesn't belong to is computed. This value indicates how different the data point is from data points in other clusters.

The Silhouette score is calculated using the formula as shown in Equation 3.5.

$$\text{Silhouette Score} = \frac{b(i) - a(i)}{\max(a(i), b(i))} \tag{3.5}$$

By taking the average of the Silhouette scores calculated for each data point, an overall Silhouette score is obtained, which measures the success of clustering results. Typically, a silhouette score of 0.5 or higher is considered to indicate a reasonably good clustering. However, it is important to note that an ideal score is 1, and a score less than 0 indicates that the clustering is poor and the sample is probably assigned to the wrong cluster (Rousseeuw, 1987).

### 3.8 Calculation of Accessibility Score by PTWAI

The accessibility score of wards for each POI was calculated based on the thresholds as per clusters defined by k medoids. Then the accessibility of POI was weight averaged on basis of number of people working for work domain and number of students for education domain as shown in Equation 3.6 and 3.7 respectively. For health domain, the accessibility for each ward was obtained after averaging the accessibility for all hospitals as illustrated in Equation 3.8.

$$\begin{aligned}&Weighted\ Accessibility\ for\ Work\ Domain\\&= \sum_{1}^{j}\left(Accessibility\ score_{(i,j)} \times \frac{People\ working\ in\ ward\ j}{Total\ workers}\right)\end{aligned} \tag{3.6}$$

$$\begin{aligned}&Weighted\ Accessibility\ for\ Education\ Domain\\&= \sum_{1}^{j}\left(Accessibility\ score_{(i,j)} \times \frac{People\ studying\ in\ j}{Total\ students}\right)\end{aligned} \tag{3.7}$$

$$\begin{aligned}&Weighted\ Accessibility\ for\ Health\ Domain\\&= \sum_{1}^{j}\left(Accessibility\ score_{(i,j)} \times \frac{Weight\ of\ hospital\ j}{Total\ weight}\right)\end{aligned} \tag{3.8}$$

Then the accessibility across the domains was added to get the PTWAI of the wards as shown in Equation 3.9. Therefore, for each domain the ward accessibility ranged from 0-n;

where n will be (number of clusters-1) as per elbow plot and the PTWAI for three domains will be grouped into n number of ranges.

$$\boldsymbol{PTWAI} \;\; = Weighted\ Accessibility\ Score\ for\ (Work + Education + Health\ Domains) \qquad (3.9)$$

In research done by Mavoa et al. (2012), the PTWAI for each parcel is a value ranging from 0 to 20 (for five domains i.e. education, health, shopping, financial and social). The accessibility labels were Very low, Low, Medium, High and Very high for scores ranging from 0-4, 5-8, 9-12, 13-16 and 17-20 respectively. Since in our case the PTWAI scores ranged from 0-15 accessibility labels was assigned as Very Low, Low, Medium, High and Very High with scores ranging from 0-3, 3-6, 6-9, 9-12 and 12-15 respectively.

### 3.9 Comparison of Accessibility and Equity

The aim of the research was to generate the accessibility score of the wards and highlight the low accessibility areas in terms of work, education or health for future planning purposes. The comparison of the accessibility and the low-income household proportion would also help analyze if the accessibility is provided to poor households and captive riders or not. Gini coefficient and Lorenz curve was used to calculate the disparity of accessibility across wards. The Lorenz curve is used to visualize and analyze inequality in a distribution, most commonly in income or wealth, but it can also be applied to other variables like accessibility. The Gini coefficient, or Gini index, is the most commonly used measure of inequality. It was developed by Italian statistician Corrado Gini (1884–1965) and is named after him (Hasell, 2023). The mean accessibility level across different income levels and the spearman correlation coefficient of accessibility with proportion of household in different income levels was calculated.

# CHAPTER 4: RESULTS AND DISCUSSION

## 4.1 Clustering of Travel Times by K-Medoids

The travel time ranges in table 2.1 may not be directly applicable to a geographically and economically distinct region such as the Kathmandu Valley, where public transport systems and their coverage differ significantly. So, to determine the accessibility scoring specific to the urban region of Nepalese context, after generating a 247×247 travel time matrix (for work domain), the travel times were extracted and converted into a one-dimensional array, resulting in a total of 61,009 travel time values. To categorize these travel times into meaningful groups, clustering analysis was performed using the elbow method to determine the optimal number of clusters. The elbow method was implemented in Python, where the inertia values representing the sum of distances between data points and their assigned cluster medoids were computed for different values of $k$. By plotting the inertia values against the number of clusters, a characteristic curve known as the elbow plot was obtained, as shown in Figure 4.1.

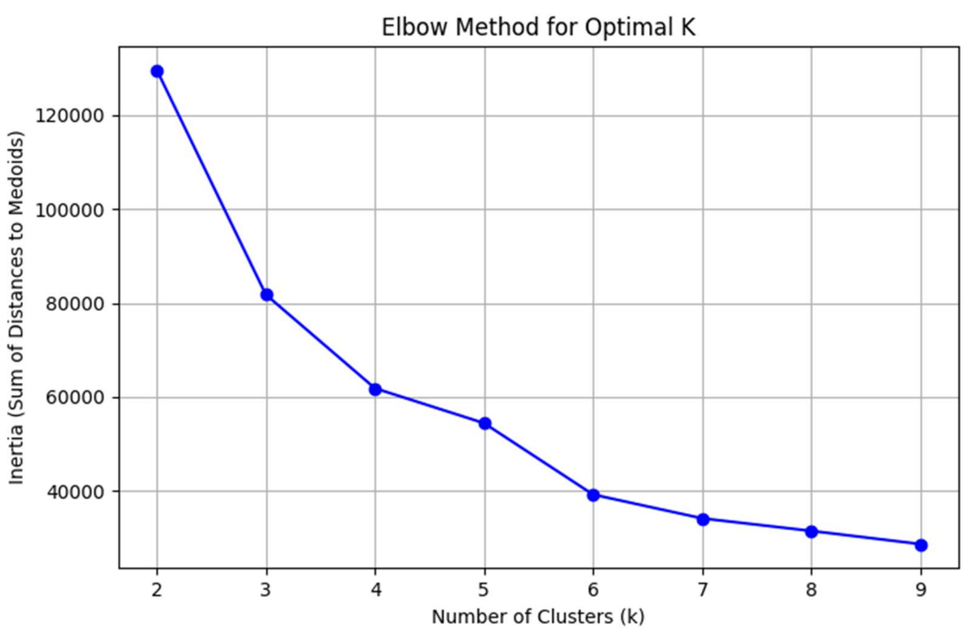


Figure 4.1: Elbow Plot

From the elbow plot, a noticeable bend, or "elbow point," was observed at k=6, indicating the optimal number of clusters. This point represents the stage where adding more clusters results in a diminishing reduction in inertia, suggesting that further increasing k would not significantly improve clustering efficiency. Thus, based on the elbow method, the travel times were optimally grouped into six clusters for further analysis.

## 4.2 Determination of Threshold Values for Different Accessibility Scores

To classify the travel time data into meaningful categories, the K-medoids clustering algorithm was applied in Python. This algorithm was chosen due to its robustness in handling outliers and its ability to produce well-defined clusters by minimizing the dissimilarities between data points and representative medoids. Using the optimal number of six clusters determined from the elbow plot, the K-medoids algorithm grouped the travel time values into distinct ranges. Each cluster was mapped to an accessibility score on a scale from zero to five, where zero represents the least accessible areas and five represents the most accessible ones.

The classification of these clusters, along with their corresponding accessibility scores, is represented in Figure 4.2, while Table 4.1 provides a detailed breakdown of the travel time ranges within each cluster.

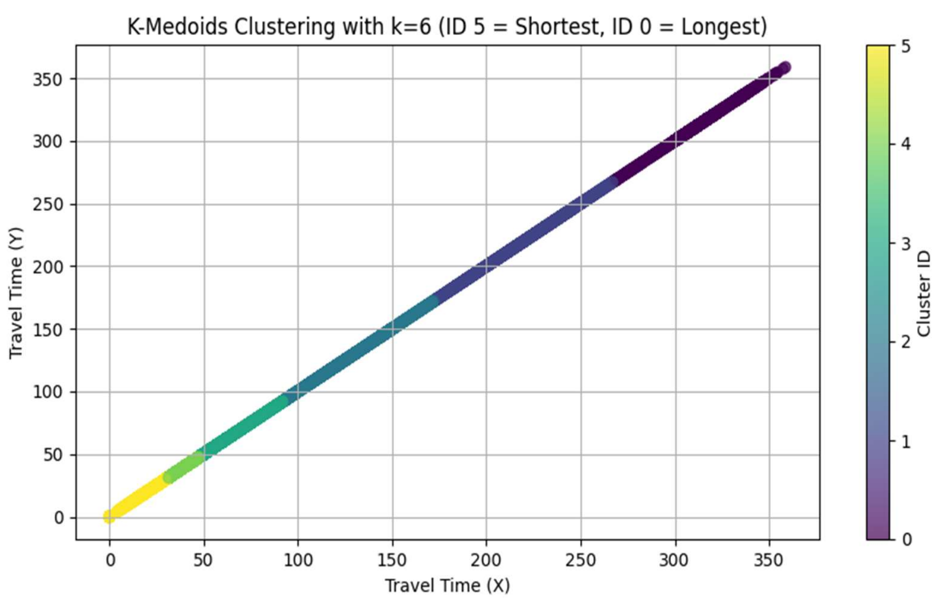


Figure 4.2: K Medoids Clustering

Table 4.1: Threshold Travel Time Values for Different Accessibility Scores

| Accessibility score | Threshold Travel Times (minutes) |
|---|---|
| 5 | 0-31.17 |
| 4 | 31.17-48.14 |
| 3 | 48.14-92.33 |
| 2 | 92.33-172.48 |
| 1 | 172.48-267.04 |
| 0 | >267.04 |

To know how well the clusters were formed, silhouettes plot for various clusters were developed. Silhouettes plot of accessibility scores for six level of thresholds for travel times is shown in Figure 4.3. The average Silhouette score for six number of clusters were found to be 0.5594. Thus, cluster groups of this study are good clusters as silhouette score are greater than 0.5 (Rousseeuw, 1987).

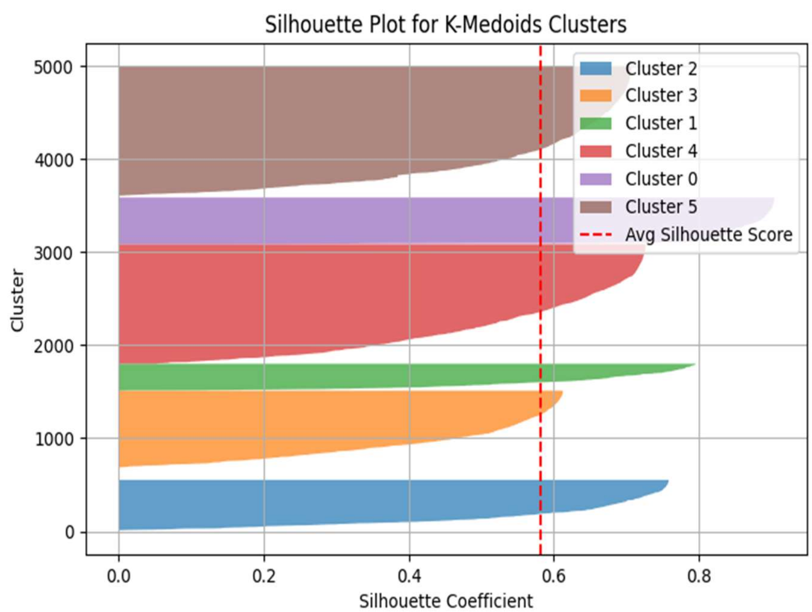


Figure 4.3: Silhouette Plot

### 4.3 Work Accessibility Score Analysis by Ranges

Table 4.2 categorizes wards in Kathmandu Valley based on their Accessibility scores for work domain, which indicate the accessibility of public transportation based on travel time to reach work point of interests. The results show 31 wards (2.7% population) have a very low accessibility score (<1), indicating poor walk accessibility to public transport. 13 wards (3.1% population) fall within the low range (1–2). 51 wards (10.5% population) exhibit a moderate work accessibility score (2-3), meaning these areas have slightly better access to work using public transportation. 16.2% of the valley's population and 40% of the valley's wards are within lower to moderate accessibility. The presence of 31 wards with very low accessibility indicates gaps in the public transport network that may require targeted interventions in the work domain. Figure 4.4 represents the work accessibility by public transportation mapping of wards of Kathmandu Valley.

Table 4.2: Population across Work Accessibility Ranges

| Ranges | Accessibility | Wards | Population |
|---|---|---|---|
| <1 | Very Low | 31 | 2.7% |
| 1-2 | Low | 13 | 3.1% |
| 2-3 | Moderate | 51 | 10.5% |
| 3-4 | High | 117 | 48.3% |
| >4 | Very High | 34 | 35.5% |

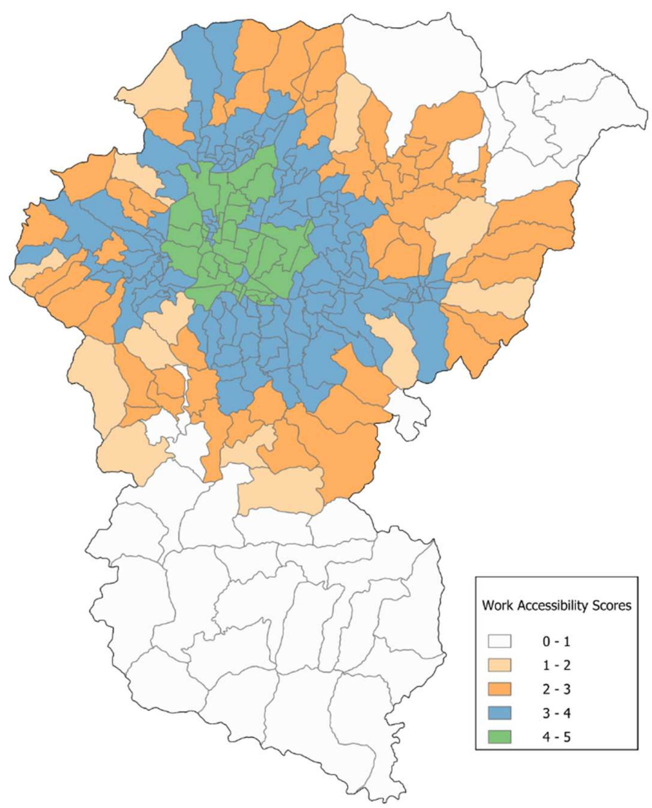


Figure 4.4: Work Accessibility Mapping of Wards

## 4.4 Municipality Wise Work Accessibility Calculation

Table 4.3 presents the distribution of wards across different municipalities based on their work accessibility categories—Very Low, Low, Medium, High, and Very High—along with the average work accessibility for each municipality. Kathmandu (4.061) and Lalitpur (3.711) have the highest average work accessibility, indicating superior public transport accessibility, with most of their wards falling in the High and Very High categories. Bhaktapur (3.484), Madhyapur Thimi (3.435), and Tokha (3.635) also show high accessibility, whereas rural and less-developed municipalities such as Mahankal (0.064), Konjyosom (0.701), and Shankharapur (1.589) exhibit Very Low accessibility, suggesting limited public transport reach. Some municipalities, like Godawari (2.328) and Changunarayan (2.455), show moderate accessibility with wards distributed across different categories. This highlights significant disparities in public transport access across municipalities, with urban centers generally having better wok accessibility than peripheral areas.

Table 4.3: Municipality Wise Average Work Accessibility

| Municipality | No of wards | | | | | Average Work Accessibility |
|---|---|---|---|---|---|---|
| | Very low | Low | Medium | High | Very High | |
| Bagmati | 7 | 0 | 0 | 0 | 0 | 0.280 |
| Godawari | 3 | 2 | 6 | 3 | 0 | 2.328 |
| Konjyosom | 5 | 0 | 0 | 0 | 0 | 0.701 |
| Lalitpur | 0 | 0 | 2 | 15 | 12 | 3.711 |
| Mahalaxmi | 1 | 0 | 1 | 7 | 1 | 3.104 |
| Mahankal | 6 | 0 | 0 | 0 | 0 | 0.064 |
| Bhaktapur | 0 | 0 | 0 | 10 | 0 | 3.484 |
| Changunarayan | 0 | 2 | 7 | 0 | 0 | 2.455 |
| Madhyapur Thimi | 0 | 0 | 0 | 9 | 0 | 3.435 |
| Suryabinayak | 0 | 1 | 2 | 7 | 0 | 3.046 |
| Budhanilakantha | 0 | 0 | 5 | 8 | 0 | 3.051 |
| Chandragiri | 0 | 1 | 6 | 8 | 0 | 3.126 |
| Dakshinkali | 2 | 3 | 4 | 0 | 0 | 1.803 |
| Gokarneshwor | 1 | 1 | 3 | 4 | 0 | 2.601 |
| Kageshwori Manahora | 0 | 0 | 5 | 4 | 0 | 2.874 |
| Kathmandu | 0 | 0 | 0 | 11 | 21 | 4.061 |
| Kirtipur | 0 | 1 | 0 | 9 | 0 | 3.401 |
| Nagarjun | 0 | 1 | 3 | 6 | 0 | 2.986 |
| Shankharapur | 6 | 0 | 3 | 0 | 0 | 1.589 |
| Tarakeshwor | 0 | 1 | 2 | 8 | 0 | 3.034 |
| Tokha | 0 | 0 | 2 | 9 | 0 | 3.635 |

## 4.5 Education Accessibility Score Analysis by Ranges

Table 4.4 categorizes wards in Kathmandu Valley based on their Accessibility scores for education domain, which indicate the accessibility of public transportation to higher education pursuing students. Similarly, Figure 4.5 represents the education accessibility by public transportation mapping of wards of Kathmandu Valley.

Table 4.4: Population across Education Accessibility Ranges

| Ranges | Accessibility | Wards | Higher Education Student |
|---|---|---|---|
| <1 | Very Low | 36 | 1.3% |
| 1-2 | Low | 28 | 5.4% |
| 2-3 | Moderate | 37 | 8.2% |
| 3-4 | High | 94 | 38.4% |
| >4 | Very High | 52 | 46.7% |

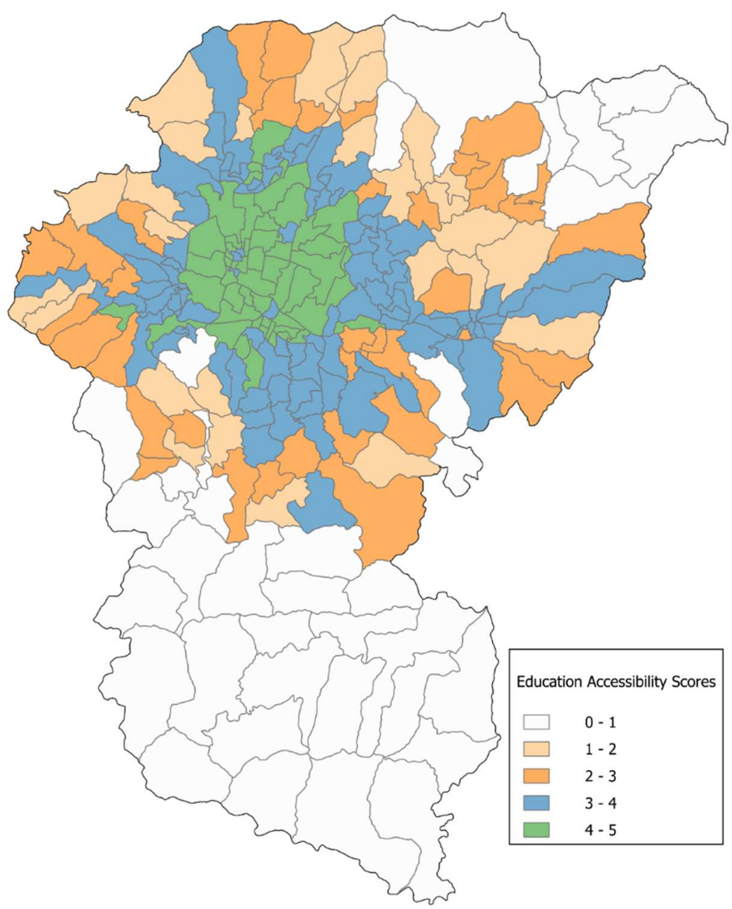


Figure 4.5: Education Accessibility Mapping of Wards

The results show 36 wards (1.3% student population) have a very low accessibility score (<1), indicating poor accessibility to public transport. 28 wards (5.4% population) fall within the low range (1–2). 37 wards (8.2% population) exhibit a moderate work accessibility score (2-3); meaning these areas have slightly better access to work using public transportation. 14.9% of the valley's higher education student population and 40.9% of the valley's wards are within lower to moderate accessibility. The presence of 36 wards with very low accessibility indicates gaps in the public transport network that may require targeted interventions in the education domain.

### 4.6 Municipality Wise Education Accessibility Calculation

Table 4.5 presents the distribution of wards in different municipalities of Kathmandu Valley based on their education accessibility levels, categorized as Very Low, Low, Medium, High, and Very High. It also provides the average education accessibility score for each municipality.

Table 4.5 : Municipality Wise Average Education Accessibility

| Municipality | No of wards | | | | | Average Education Accessibility |
|---|---|---|---|---|---|---|
| | Very low | Low | Medium | High | Very High | |
| Bagmati | 7 | 0 | 0 | 0 | 0 | 0.001 |
| Godawari | 4 | 2 | 5 | 3 | 0 | 1.877 |
| Konjyosom | 5 | 0 | 0 | 0 | 0 | 0.001 |
| Lalitpur | 0 | 2 | 0 | 12 | 15 | 3.815 |
| Mahalaxmi | 1 | 0 | 1 | 7 | 1 | 3.104 |
| Mahankal | 6 | 0 | 0 | 0 | 0 | 0.064 |
| Bhaktapur | 0 | 0 | 1 | 9 | 0 | 3.506 |
| Changunarayan | 0 | 2 | 2 | 5 | 0 | 2.075 |
| Madhyapur Thimi | 0 | 0 | 0 | 8 | 1 | 3.505 |
| Suryabinayak | 1 | 0 | 5 | 4 | 0 | 2.745 |
| Budhanilakantha | 0 | 4 | 2 | 7 | 0 | 2.872 |
| Chandragiri | 0 | 2 | 6 | 6 | 1 | 2.955 |
| Dakshinkali | 4 | 2 | 3 | 0 | 0 | 1.335 |
| Gokarneshwor | 2 | 2 | 1 | 4 | 0 | 2.432 |
| Kageshwori Manahora | 0 | 2 | 3 | 4 | 0 | 2.701 |
| Kathmandu | 0 | 0 | 0 | 4 | 28 | 4.249 |
| Kirtipur | 0 | 1 | 0 | 8 | 1 | 3.443 |
| Nagarjun | 0 | 1 | 3 | 6 | 0 | 2.986 |
| Shankharapur | 6 | 0 | 3 | 0 | 0 | 0.816 |
| Tarakeshwor | 0 | 3 | 1 | 7 | 0 | 2.921 |
| Tokha | 0 | 0 | 2 | 5 | 4 | 3.611 |

Municipalities such as Kathmandu (4.249), Lalitpur (3.815), and Tokha (3.611) have the highest education accessibility, with most of their wards classified under the High or Very High categories. In contrast, municipalities like Bagmati (0.001), Konjyosom (0.001), and Mahankal (0.064) have the lowest education accessibility, as most of their wards fall under Very Low accessibility.

### 4.7 Health Accessibility Score Analysis by Ranges

Table 4.6 categorizes wards in Kathmandu Valley based on their Accessibility scores for health domain, which indicate the accessibility of public transportation to insurance offering hospitals by HIB. The results show 37 wards (5.4% differently abled population and 4.2% old age population) have a very low accessibility score (<1), indicating poor accessibility to public transport. 30 wards (9.6% differently abled population and 7.9% old age population) fall within the low range (1–2). 46 wards (16.6% differently abled population and 14.9% old age population) exhibit a moderate work accessibility score (2-3); meaning these areas have slightly better access to work using public transportation. 31.6% of the differently abled population and 26.9% of the old age population are within lower to moderate accessibility in the health domain. 45.75% of the valley's wards are within lower to moderate accessibility. The presence of 37 wards with very low accessibility indicates gaps in the public transport network that may require targeted interventions in the health domain.

Table 4.6: Population across Health Accessibility Ranges

| Ranges | Accessibility | Wards | Disabled Population | Old Age Population |
|---|---|---|---|---|
| <1 | Very Low | 37 | 5.4% | 4.2% |
| 1-2 | Low | 30 | 9.6% | 7.9% |
| 2-3 | Moderate | 46 | 16.6% | 14.9% |
| 3-4 | High | 119 | 57.8% | 60.3% |
| >4 | Very High | 15 | 10.59% | 12.7% |

Figure 4.6 represents the health accessibility by public transportation mapping of wards of Kathmandu Valley.

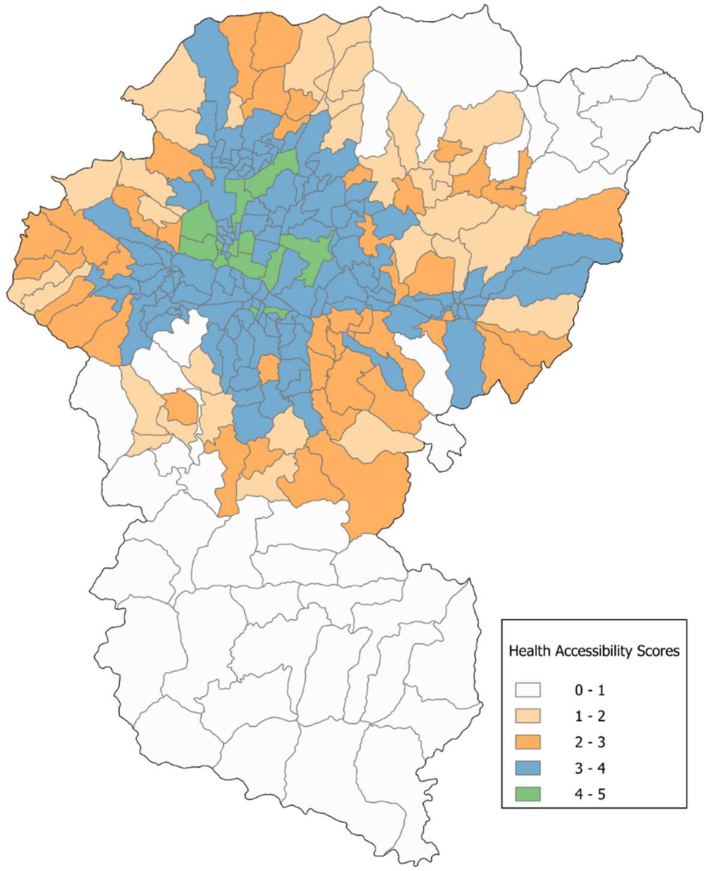


Figure 4.6: Health Accessibility Mapping of Wards

## 4.8 Municipality Wise Health Accessibility Calculation

The Table 4.7 categorizes the wards of different municipalities in Kathmandu Valley based on their health accessibility levels, ranging from Very Low to Very High, and provides the average health accessibility score for each municipality. Municipalities such as Kathmandu (3.870), Lalitpur (3.493), and Tokha (3.432) have the highest health accessibility, with most of their wards falling under High or Very High categories. In contrast, Bagmati (0.020), Konjyosom (0.007), and Mahankal (0.014) have the lowest accessibility, as all their wards are in the Very Low category, indicating poor access to healthcare services. This suggests that urban areas like Kathmandu, Lalitpur, and Bhaktapur have significantly better insured healthcare accessibility due to the presence of well-developed medical facilities and hospitals.

Table 4.7 : Municipality Wise Average Health Accessibility

| Municipality | No of wards | | | | | Average Health Accessibility |
|---|---|---|---|---|---|---|
| | Very low | Low | Medium | High | Very High | |
| Bagmati | 7 | 0 | 0 | 0 | 0 | 0.020 |
| Godawari | 4 | 3 | 5 | 2 | 0 | 1.172 |
| Konjyosom | 5 | 0 | 0 | 0 | 0 | 0.007 |
| Lalitpur | 0 | 2 | 1 | 23 | 3 | 3.493 |
| Mahalaxmi | 1 | 0 | 5 | 4 | 0 | 2.763 |
| Mahankal | 6 | 0 | 0 | 0 | 0 | 0.014 |
| Bhaktapur | 0 | 0 | 1 | 9 | 0 | 3.304 |
| Changunarayan | 0 | 5 | 2 | 2 | 0 | 2.006 |
| Madhyapur Thimi | 0 | 0 | 1 | 8 | 0 | 3.294 |
| Suryabinayak | 1 | 0 | 6 | 3 | 0 | 2.652 |
| Budhanilakantha | 0 | 4 | 3 | 6 | 0 | 2.691 |
| Chandragiri | 0 | 2 | 7 | 6 | 0 | 2.840 |
| Dakshinkali | 4 | 4 | 1 | 0 | 0 | 1.266 |
| Gokarneshwor | 2 | 2 | 1 | 4 | 0 | 2.133 |
| Kageshwori Manahora | 0 | 2 | 4 | 3 | 0 | 2.481 |
| Kathmandu | 0 | 0 | 0 | 20 | 12 | 3.870 |
| Kirtipur | 1 | 0 | 0 | 9 | 0 | 3.158 |
| Nagarjun | 0 | 3 | 3 | 4 | 0 | 2.598 |
| Shankharapur | 6 | 0 | 3 | 0 | 0 | 0.796 |
| Tarakeshwor | 0 | 3 | 1 | 7 | 0 | 2.675 |
| Tokha | 0 | 0 | 2 | 9 | 0 | 3.432 |

### 4.9 PTWAI Analysis

The accessibility across different domains were added to get the PTWAI of the wards ranging from 0 to 15. The accessibility labels were assigned as Very Low, Low, Medium, High and Very High with scores ranging from 0-3, 3-6, 6-9, 9-12 and 12-15 respectively. The PTWAI values of all wards are listed in Annex.

Table 4.8 categorizes wards in Kathmandu Valley based on their PTWAI scores for work, education and health domains. The results show 34 wards (3.22% population) have a very low accessibility score (<1), indicating poor accessibility to public transport. 26 wards (5.75% population) fall within the low range (1–2). 43 wards (9.46% population) exhibit a moderate work accessibility score (2-3); meaning these areas have slightly better access to work using public transportation. 18.44% of the population and 41.7% of the valley’s wards are within lower to moderate accessibility. The presence of 34 wards with very low accessibility indicates gaps in the public transport network that may require targeted interventions in the health domain. Figure 4.7 represents the PTWAI mapping of wards of Kathmandu Valley.

Table 4.8 : Population across PTWAI Ranges

| Ranges | PTWAI | Wards | Population |
|---|---|---|---|
| <3 | Very Low | 34 | 3.2% |
| 3-6 | Low | 26 | 5.8% |
| 6-9 | Moderate | 43 | 9.5% |
| 9-12 | High | 112 | 51.6% |
| >12 | Very High | 32 | 29.9% |

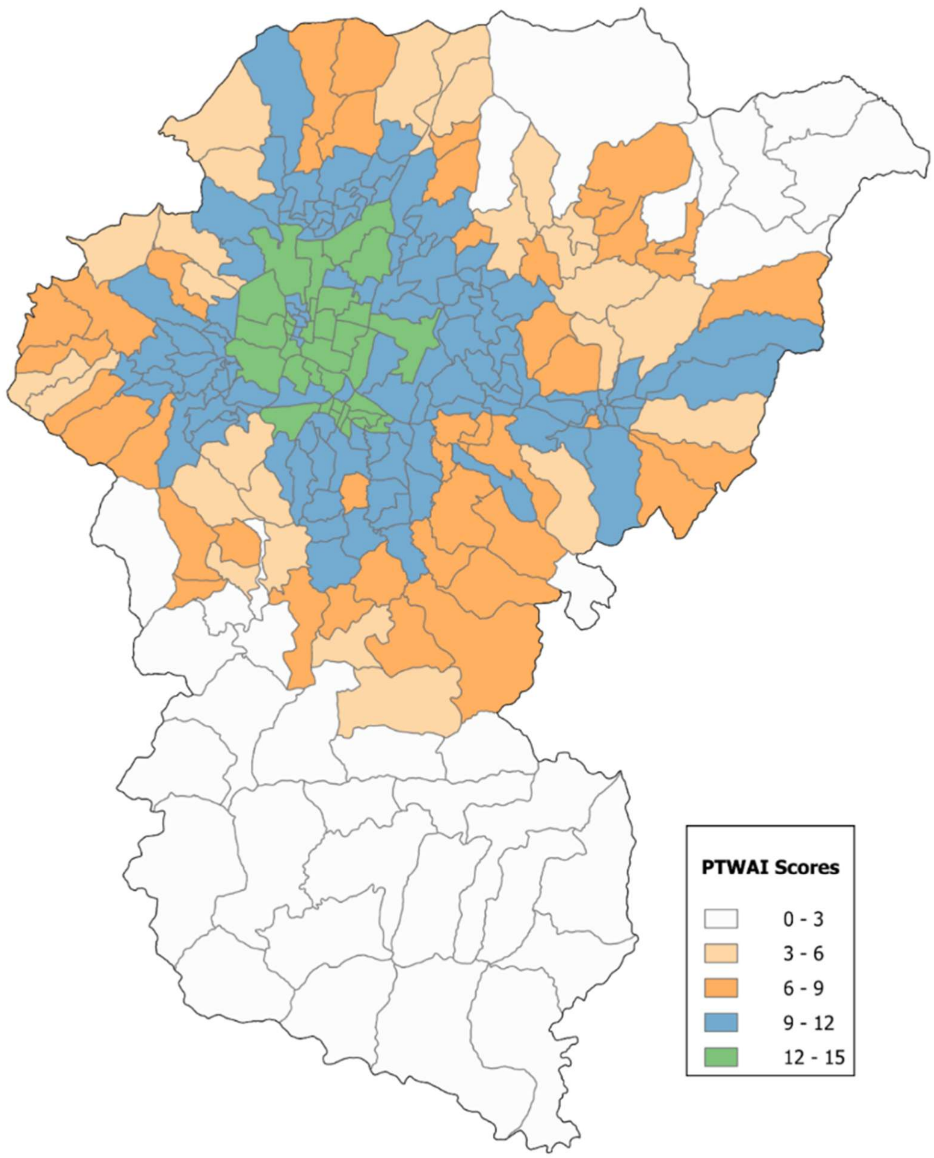


Figure 4.7: PTWAI Mapping of Wards

### 4.10 Municipality Wise PTWAI Calculation

Table 4.9 presents the distribution of wards and average scores across different municipalities based on their PTWAI categories. Kathmandu and Lalitpur followed by Tokha, Kirtipur, Madhyapur Thimi and Bhaktapur have the highest average accessibility, indicating superior public transport accessibility, with most of their wards falling in the High and Very High categories. Mahankal, Bagmati, Konjyosom exhibit lowest accessibility scores followed by Shankharapur and Godawari. Other municipalities have moderate level of accessibilities. This highlights significant disparities in public transport access across municipalities, with urban centers generally having better accessibility across work, health and education domain than peripheral areas.

Table 4.9: Municipality Wise Average PTWAI Scores

| Municipality | No of wards | | | | | Average PTWAI |
|---|---|---|---|---|---|---|
| | Very low | Low | Medium | High | Very High | |
| Bagmati | 7 | 0 | 0 | 0 | 0 | 0.301 |
| Godawari | 3 | 2 | 7 | 2 | 0 | 3.973 |
| Konjyosom | 5 | 0 | 0 | 0 | 0 | 0.709 |
| Lalitpur | 0 | 2 | 1 | 14 | 12 | 11.019 |
| Mahalaxmi | 1 | 0 | 3 | 5 | 1 | 8.841 |
| Mahankal | 6 | 0 | 0 | 0 | 0 | 0.025 |
| Bhaktapur | 0 | 0 | 1 | 9 | 0 | 10.294 |
| Changunarayan | 0 | 4 | 3 | 2 | 0 | 6.536 |
| Madhyapur Thimi | 0 | 0 | 0 | 9 | 0 | 10.233 |
| Suryabinayak | 0 | 1 | 5 | 4 | 0 | 8.461 |
| Budhanilakantha | 0 | 3 | 2 | 8 | 0 | 8.613 |
| Chandragiri | 0 | 2 | 6 | 7 | 0 | 8.956 |
| Dakshinkali | 4 | 2 | 3 | 0 | 0 | 4.404 |
| Gokarneshwor | 2 | 2 | 1 | 4 | 0 | 7.167 |
| Kageshwori Manahora | 0 | 2 | 3 | 4 | 0 | 8.055 |
| Kathmandu | 0 | 0 | 0 | 13 | 19 | 12.176 |
| Kirtipur | 0 | 1 | 0 | 9 | 0 | 10.007 |
| Nagarjun | 0 | 3 | 1 | 6 | 0 | 8.387 |
| Shankharapur | 6 | 0 | 3 | 0 | 0 | 3.201 |
| Tarakeshwor | 0 | 2 | 2 | 7 | 0 | 8.630 |
| Tokha | 0 | 0 | 2 | 9 | 0 | 10.678 |

### 4.11 Comparison of PTWAI with Gini coefficient and Lorenz Curve

The Lorenz curve is used to visualize and analyze inequality in a distribution, most commonly in income or wealth, but it can also be applied to other variables like accessibility. The Lorenz Curve for Accessibility illustrated in Figure 4.8 measures the degree of inequality in public transport accessibility across wards. The curve deviates significantly from the Line of Equality, indicating that accessibility is not uniformly distributed. This means that a smaller proportion of wards enjoy a disproportionately higher share of accessibility, while many wards have limited or poor access to public transport services. The Gini coefficient, calculated as 0.4409, quantitatively confirms this moderate level of inequality. A Gini value of 0 would signify perfect equality (Hasell, 2023), where every ward has the same accessibility, whereas a value closer to 1 would indicate severe inequality, where only a few wards have high accessibility while the rest have very little.

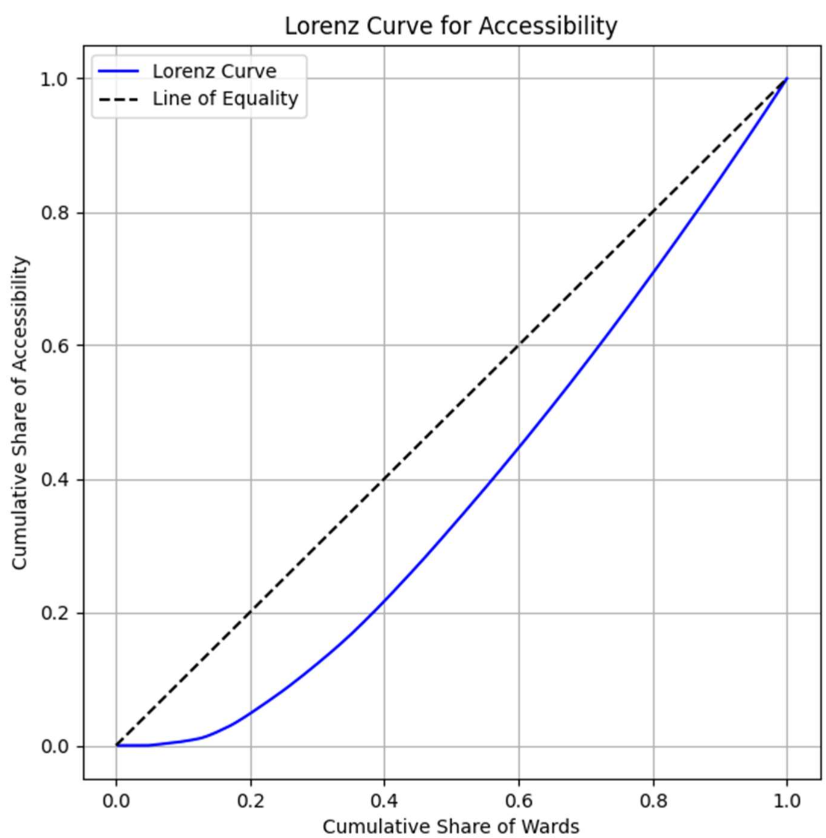


Figure 4.8: Lorenz Curve for Accessibility

### 4.12 Comparison of PTWAI with Wealth Quintiles

The Table 4.10 shows the relationship between wealth quintiles and work accessibility scores, highlighting disparities in accessibility is illustrated in Table 4.4. The poorest groups have the lowest accessibility scores (4.360 for the poorest and 7.424 for poorer households) and the strongest negative correlations with accessibility (-0.6586 and -0.4119), indicating that higher proportions of these groups are associated with lower accessibility. As proportion of richer household increases, accessibility scores improve (reaching 10.455 for the richest), and the correlation shifts positive (0.6161 for the richest), suggesting that wealthier households generally have better access to work locations using public transport. This pattern indicates a clear inequity, where accessibility is disproportionately higher for the rich and lower for the poor.

Table 4.10: Comparison of Wealth Quintiles with Accessibility

| Wealth Quintiles | Work Accessibility | Spearman Correlation with Accessibility |
|---|---|---|
| Poorest | 4.360 | -0.6586 |
| Poorer | 7.424 | -0.4119 |
| Moderate | 9.084 | 0.2358 |
| Richer | 10.239 | 0.5792 |
| Richest | 10.455 | 0.6161 |

# CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

## 5.1 Conclusion

This research assesses public transport accessibility and equity in Kathmandu Valley using the Public Transport Weighted Accessibility Index (PTWAI), focusing on access to work, education, and health services. GTFS data derived from onboard surveys and headway information is integrated into PTV Visum to estimate perceived travel times between ward centroids and POIs. Accessibility scores are weighted by domain-specific indicators such as the number of employees, students, and hospital services. Wards are then clustered using CLARA (a K-Medoids approach) to identify patterns in accessibility, and equity is evaluated through Lorenz curves, Gini coefficients, and comparisons with wealth quintiles to highlight underserved and disadvantaged areas.

The following are the conclusions drawn from numerical analysis:

- The clustering of travel times using the K-medoids method provided a structured framework to classify accessibility levels, revealing that a substantial portion of the population faces challenges in accessing employment opportunities due to poor public transport connectivity. The results indicate that 34 wards, comprising 3.2% of the population, fall within the very lowest accessibility category and 26 wards, comprising of 5.8% of population, emphasizing the need for targeted interventions in these areas.
- The wards with the highest accessibility scores predominantly belong to urban centers such as Kathmandu and Lalitpur, reflecting a stark contrast in public transport reach between core urban areas and peripheral municipalities. The municipality wise analysis further underscores these discrepancies, with rural municipalities such as Mahankal, Bagmati, Shankharapur, and Konjyosom exhibiting significantly lower PTWAI scores compared to the well-connected urban municipalities.
- Work accessibility scores reveal disparities across wards, with 31 wards (2.7% population) having very low accessibility (<1), while 34 wards (35.5% population) scored very high (4-5).

- 36 wards (1.3% student population) have very low education accessibility scores and 28 wards (5.4% student population) have low scores, highlighting gaps in public transport for students pursuing higher education.
- In regards to health domain, 37 wards (5.4% disabled population and 4.2% old age population) have very low accessibility and 30 wards (9.6 % disabled population and 7.9% old age population) have low accessibility scores to insured health facilities.
- The inequality in accessibility is further substantiated by the Gini coefficient of 0.4409, suggesting a moderate level of disparity in public transport reach. The Lorenz curve confirms that accessibility is unevenly distributed, with a small proportion of wards enjoying significantly better accessibility while a considerable portion of the valley remains underserved.
- The relationship between accessibility and wealth quintiles reveals that households in lower wealth quintiles have significantly lower accessibility scores, with negative correlations indicating that economically disadvantaged groups experience greater barriers in reaching employment locations. This disparity suggests that public transport inadequacies may be reinforcing socio-economic inequalities by limiting mobility options for the less affluent.

## 5.2 Recommendations for Future Study

Due to absence of mode choices and shares data from individual wards, this study assumes that all the population in a ward for calculation of underserved populations. Future research can be conducted considering detail mode shares and underserved population for public transport shares only. Additionally, the rising ride hailing bikes and taxi services has not been considered for analysis. Similarly, study on the overall accessibility after the integration of public transport with other mobility solutions such as ride hailing services is also recommended. Integrating residential areas, exact work locations and settlements within a ward separately would provide a more comprehensive understanding of transport accessibility. The future study can cover all health facilities and all educational institution covering school for complete analysis. Additionally, expanding similar research beyond Kathmandu Valley to other urban and rural areas in Nepal would help compare accessibility and equity trends. Rural transport accessibility, particularly in hilly and remote regions, needs further analysis to identify gaps in mobility services and recommend appropriate interventions. The effectiveness of government subsidies (motor vehicle taxation), fare reductions, and service improvements in enhancing public transport accessibility for underserved populations can also be analyzed.

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# ANNEX-I

## Headway and Travel time data from On-Board Survey

| SN | Route Name | Headway (minutes) | Total Trip Time |
|---|---|---|---|
| 1 | Balkot Koteshwor Tripureshwor Kalanki (OutBound) | 10 | 1:18:18 |
| | Balkot Koteshwor Tripureshwor Kalanki (Return) | 10 | 1:12:12 |
| 2 | Bhaktapur PuranoThimi Koteshowr Bagbazar (OutBound) | 5 | 1:27:28 |
| | Bhaktapur PuranoThimi Koteshowr Bagbazar (Return) | 5 | 1:14:48 |
| 3 | Bhaktapur(Dudhpati) Koteshowr Lagankhel (OutBound) | 15 | 1:10:43 |
| | Bhaktapur(Dudhpati) Koteshowr Lagankhel (Return) | 25 | 1:37:47 |
| 4 | Bhaktapur(Dudhpati) Koteshowr Nayabuspark (OutBound) | 15 | 1:34:33 |
| | Bhaktapur(Dudhpati) Koteshowr Nayabuspark (Return) | 25 | 2:06:08 |
| 5 | Biruwa Kaushaltar Koteshwor Baneshwor Kalanki (OutBound) | 10 | 1:51:05 |
| | Biruwa Kaushaltar Koteshwor Baneshwor Kalanki (Return) | 15 | 1:21:54 |
| 6 | Bode Mulpani Chabahil Chakrapath samakhusi Gongabu (OutBound) | 15 | 1:30:46 |
| | Bode Mulpani Chabahil Chakrapath samakhusi Gongabu (Return) | 15 | 2:32:43 |
| 7 | Budanilkantha to Koteshwor (OutBound) | 5 | 1:18:39 |
| | Budanilkantha to Koteshwor (Return) | 10 | 1:17:43 |
| 8 | Bungmati-Bhaisepati-Ekantakuna-Kupandole-NAC-Ratnapark (OutBound) | 30 | 0:53:36 |
| | Bungmati-Bhaisepati-Ekantakuna-Kupandole-NAC-Ratnapark (Return) | 40 | 0:44:12 |
| 9 | Chappalkarkhana Dhalku to NAC (OutBound) | 15 | 0:36:43 |
| | Chappalkarkhana Dhalku to NAC (Return) | 20 | 1:09:34 |
| 10 | Dahachowk Kalanki NAC(Ratnapark) (OutBound) | 10 | 0:56:43 |
| | Dahachowk Kalanki NAC(Ratnapark) (Return) | 5 | 1:35:30 |
| 11 | Duwakot Sallaghari Thimi Koteshowr Naya baneshowr Bagbazaar (OutBound) | 20 | 1:28:52 |
| | Duwakot Sallaghari Thimi Koteshowr Naya baneshowr Bagbazaar (Return) | 15 | 1:55:25 |
| 12 | Godawari NAC(Ratnapark) (OutBound) | 10 | 1:27:43 |
| | Godawari NAC(Ratnapark) (Return) | 10 | 1:22:36 |

| | | | |
|---|---|---|---|
| 13 | Gokarna Cabahil Dillibazar Ratnapark (OutBound) | 5 | 0:52:52 |
| | Gokarna Cabahil Dillibazar Ratnapark (Return) | 5 | 0:51:09 |
| 14 | Gokarna Chabhil Maharajgunj Balaju Kalanki (OutBound) | 5 | 1:52:46 |
| | Gokarna Chabhil Maharajgunj Balaju Kalanki (Return) | 5 | 1:56:21 |
| 15 | Gongabu Naya Buspark to Bhaktapur (Bansbari) (OutBound) | 4 | 1:58:19 |
| | Gongabu Naya Buspark to Bhaktapur (Bansbari) (Return) | 5 | 1:42:05 |
| 16 | Gongabu Naya Buspark to Chyamasingh(Kamal binayak buspark) (OutBound) | 10 | 1:55:42 |
| | Gongabu Naya Buspark to Chyamasingh(Kamal binayak buspark) (Return) | 10 | 1:56:09 |
| 17 | Gongabu Naya Buspark to Lagankhel (OutBound) | 7 | 1:06:40 |
| | Gongabu Naya Buspark to Lagankhel (Return) | 7 | 1:01:26 |
| 18 | HarHara Mahadev Jadibuti Koteshowr Thapathali Kalimati Balkhu Ekantakuna Jawlakhel Thapathali Baneshowr Pepsikola HarHara Mahadev | 5 | 2:19:06 |
| 19 | Hattiban-Lagankhel-Thapathali-Ratnapark (OutBound) | 5 | 0:52:31 |
| | Hattiban-Lagankhel-Thapathali-Ratnapark (Return) | 5 | 0:47:23 |
| 20 | Ichangu Karakhanachok Swoyambhu Dallu Nayabazar NAC(Ratnapark) (OutBound) | 20 | 1:03:27 |
| | Ichangu Karakhanachok Swoyambhu Dallu Nayabazar NAC(Ratnapark) (Return) | 20 | 0:56:53 |
| 21 | Jagati-Doleswor (OutBound) | 20 | 0:19:06 |
| | Jagati-Doleswor (Return) | 10 | 0:13:25 |
| 22 | Jalabinayak Magargaun Bhaisepati Nakhhu Ekantakuna Jawalakhel Pulchowk Kupandole Thapathali Singhadurbar NAC Ratnapark (OutBound) | 10 | 0:57:17 |
| | Jalabinayak Magargaun Bhaisepati Nakhhu Ekantakuna Jawalakhel Pulchowk Kupandole Thapathali Singhadurbar NAC Ratnapark (Return) | 10 | 1:36:07 |
| 23 | Jamal Lamatar (OutBound) | 3 | 1:33:07 |
| | Jamal Lamatar (Return) | 10 | 1:27:45 |
| 24 | Jamal Tripureshwor Satdobato Tikabhairab Lele (OutBound) | 3 | 1:39:12 |
| | Jamal Tripureshwor Satdobato Tikabhairab Lele (Return) | 5 | 1:45:18 |
| 25 | Jhor NAC(Ratnapark) (OutBound) | 10 | 1:12:40 |
| | Jhor NAC(Ratnapark) (Return) | 10 | 1:09:33 |
| 26 | Kalanki Koteshwor Chyamasingha (OutBound) | 3 | 1:53:14 |
| | Kalanki Koteshwor Chyamasingha (Return) | 5 | 1:41:16 |
| 27 | Kalanki Ratnapark (OutBound) | 2 | 0:16:34 |
| | Kalanki Ratnapark (Return) | 5 | 0:31:13 |
| 28 | Kamal binayak to Chareli (OutBound) | 30 | 1:19:55 |
| | Kamal binayak to Chareli (Return) | 30 | 0:34:52 |
| 29 | Kamalbinayak Nagarkot (OutBound) | 45 | 1:11:09 |

| | | | |
|---|---|---|---|
| | Kamalbinayak Nagarkot (Return) | 45 | 1:41:39 |
| 30 | Kamalbinayak Sallaghari Koteshowr Bagbazar (OutBound) | 10 | 1:18:32 |
| | Kamalbinayak Sallaghari Koteshowr Bagbazar (Return) | 10 | 1:19:20 |
| 31 | Kapan Phaika Mahankal Baluwatar Hattisar Putalisadak Thapagaun Koteswor Balkumari Tikathali (OutBound) | 4 | 1:41:51 |
| | Kapan Phaika Mahankal Baluwatar Hattisar Putalisadak Thapagaun Koteswor Balkumari Tikathali (Return) | 4 | 1:36:50 |
| 32 | Kapan(Gamcha) chabahil Mitrapark Kalopool Putalisadak Baghbazar Sundhara Tripureshwor Kalimati Kalanki Swoyambhu Gongabu Nayabuspark Basundhara Chakrapath Bansbari Special chowk Bhangal Kapan (Gamcha) | 10 | 2:47:40 |
| 33 | Kavresthali NAC(Ratnapark) (OutBound) | 5 | 0:56:37 |
| | Kavresthali NAC(Ratnapark) (Return) | 5 | 0:56:20 |
| 34 | Kharibot (Dhital Chowk)-Banasthali-Balaju-Lainchaur-NAC (OutBound) | 15 | 0:34:25 |
| | Kharibot (Dhital Chowk)-Banasthali-Balaju-Lainchaur-NAC (Return) | 15 | 0:33:37 |
| 35 | Khokana Bhaisepati Nakhhu Ekantakuna Jawalakhel Pulchowk Kupandole Thapathali Singhadurbar NAC Ratnapark (OutBound) | 15 | 0:45:51 |
| | Khokana Bhaisepati Nakhhu Ekantakuna Jawalakhel Pulchowk Kupandole Thapathali Singhadurbar NAC Ratnapark (Return) | 20 | 1:02:46 |
| 36 | Kirtipur-Balkhu-Kalimati-NAC (Bus) (OutBound) | 30 | 0:49:41 |
| | Kirtipur-Balkhu-Kalimati-NAC (Bus) (Return) | 30 | 0:44:39 |
| 37 | Kirtipur-Balkhu-Kalimati-NAC (Micro) (OutBound) | 2 | 0:53:39 |
| | Kirtipur-Balkhu-Kalimati-NAC (Micro) (Return) | 5 | 1:04:25 |
| 38 | Kirtipur-Balkhu-Mahalaxmisthan-Lagankhel (OutBound) | 10 | 0:41:48 |
| | Kirtipur-Balkhu-Mahalaxmisthan-Lagankhel (Return) | 10 | 0:43:59 |
| 39 | Lagankhel - Dandathok (OutBound) | 20 | 0:58:14 |
| | Lagankhel - Dandathok (Return) | 10 | 1:13:14 |
| 40 | Lagankhel - Lamatar Dhungin (OutBound) | 10 | 1:19:27 |
| | Lagankhel - Lamatar Dhungin (Return) | 10 | 1:07:39 |
| 41 | Lagankhel Baneshwor Koteshwor Satdobato Lagankhel | 3 | 1:10:51 |
| 42 | Lagankhel Jwalakhel Ekantapur Bhasepati Bungmati Farsidol (OutBound) | 10 | 1:16:06 |
| | Lagankhel Jwalakhel Ekantapur Bhasepati Bungmati Farsidol (Return) | 40 | 1:08:02 |
| 43 | Lagankhel Jwalakhel Ekantapur Bhasepati Chunikhel Champi Tikabhairav (OutBound) | 60 | 1:07:18 |
| | Lagankhel Jwalakhel Ekantapur Bhasepati Chunikhel Champi Tikabhairav (Return) | 60 | 1:43:30 |
| 44 | Lagankhel Jwalakhel Ekantapur Bhasepati Khokana (OutBound) | 10 | 0:44:02 |

| | | | |
|---|---|---|---|
| | Lagankhel Jwalakhel Ekantapur Bhasepati Khokana (Return) | 10 | 0:29:44 |
| 45 | Lagankhel koteshwor Bhaktapur(Dudhpati) via kamalbinayak (OutBound) | 5 | 1:37:57 |
| | Lagankhel koteshwor Bhaktapur(Dudhpati) via kamalbinayak (Return) | 5 | 1:01:10 |
| 46 | Lagankhel Krishnamandir Gwarko Sanogaun Shankhadevi Lubhu (OutBound) | 10 | 0:38:02 |
| | Lagankhel Krishnamandir Gwarko Sanogaun Shankhadevi Lubhu (Return) | 15 | 1:00:03 |
| 47 | Lagankhel Newbuspark (OutBound) | 10 | 1:18:25 |
| | Lagankhel Newbuspark (Return) | 10 | 1:06:03 |
| 48 | Lagankhel Satdobato Harisiddhi Thaiba Taukhel Badikhel (OutBound) | 10 | 1:01:00 |
| | Lagankhel Satdobato Harisiddhi Thaiba Taukhel Badikhel (Return) | 10 | 0:50:50 |
| 49 | Lagankhel Satdobato Khumaltar Dholahiti Sunakoti Thecho Chapagaun Takhel (OutBound) | 10 | 0:48:53 |
| | Lagankhel Satdobato Khumaltar Dholahiti Sunakoti Thecho Chapagaun Takhel (Return) | 8 | 0:55:51 |
| 50 | Lagankhel Satdobato Khumaltar Dholahiti Sunakoti Thecho Chapagaun Takhel Lele (OutBound) | 10 | 1:45:20 |
| | Lagankhel Satdobato Khumaltar Dholahiti Sunakoti Thecho Chapagaun Takhel Lele (Return) | 20 | 1:16:26 |
| 51 | Lagankhel to Bajrabarahi (OutBound) | 10 | 0:39:50 |
| | Lagankhel to Bajrabarahi (Return) | 10 | 0:41:44 |
| 52 | Lagankhel to Bungamati (OutBound) | 10 | 0:52:45 |
| | Lagankhel to Bungamati (Return) | 10 | 0:34:59 |
| 53 | Lagankhel to Dukuchhap (Chhampi) (OutBound) | 10 | 0:41:31 |
| | Lagankhel to Dukuchhap (Chhampi) (Return) | 40 | 0:46:58 |
| 54 | Lagankhel to Godawari (OutBound) | 3 | 0:32:28 |
| | Lagankhel to Godawari (Return) | 3 | 0:38:45 |
| 55 | Lagankhel to Kittachaur (OutBound) | 30 | 1:21:39 |
| | Lagankhel to Kittachaur (Return) | 30 | 0:46:22 |
| 56 | Lagankhel to Sunakothi (OutBound) | 5 | 0:26:28 |
| | Lagankhel to Sunakothi (Return) | 5 | 0:21:47 |
| 57 | Lagankhel-Budhanilkantha (OutBound) | 10 | 1:36:56 |
| | Lagankhel-Budhanilkantha (Return) | 10 | 1:05:50 |
| 58 | Lagankhel-Chamati(Dallu) (OutBound) | 10 | 0:40:06 |
| | Lagankhel-Chamati(Dallu) (Return) | 10 | 0:40:03 |
| 59 | Lagankhel-Dakshinkali (OutBound) | 30 | 1:19:48 |
| | Lagankhel-Dakshinkali (Return) | 30 | 1:04:51 |
| 60 | Lagankhel-Jharuwasi (OutBound) | 40 | 0:54:38 |
| | Lagankhel-Jharuwasi (Return) | 15 | 0:52:57 |
| 61 | Lagankhel-ratnapark (OutBound) | 6 | 0:40:53 |
| | Lagankhel-ratnapark (Return) | 5 | 0:21:47 |

| | | | |
|---|---|---|---|
| 62 | Langol Buspark-Chovar Gate-Balkhu-Kalimati-NAC (OutBound) | 12 | 0:48:37 |
| | Langol Buspark-Chovar Gate-Balkhu-Kalimati-NAC (Return) | 12 | 1:09:58 |
| 63 | Machhegau-Satungal-Kalanki-Tripureshwor-NAC (Force) (OutBound) | 12 | 1:11:30 |
| | Machhegau-Satungal-Kalanki-Tripureshwor-NAC (Force) (Return) | 12 | 1:33:15 |
| 64 | Machhegau-Satungal-Kalanki-Tripureshwor-NAC (Minibus) (OutBound) | 12 | 0:57:27 |
| | Machhegau-Satungal-Kalanki-Tripureshwor-NAC (Minibus) (Return) | 12 | 1:13:03 |
| 65 | Matatirtha-Kalanki-Tripureshwor-NAC (OutBound) | 12 | 1:25:57 |
| | Matatirtha-Kalanki-Tripureshwor-NAC (Return) | 12 | 1:04:06 |
| 66 | Mulpani Baneshwor Kalanki Thankot (OutBound) | 7 | 2:41:52 |
| | Mulpani Baneshwor Kalanki Thankot (Return) | 7 | 2:20:43 |
| 67 | NAC Baneshwor Airport Chabahil Gongabu Naya Buspark (OutBound) | 10 | 1:32:54 |
| | NAC Baneshwor Airport Chabahil Gongabu Naya Buspark (Return) | 15 | 1:39:34 |
| 68 | NAC to Chyamasingha (OutBound) | 5 | 1:36:30 |
| | NAC to Chyamasingha (Return) | 7 | 1:17:16 |
| 69 | NAC to Gagalphedi (OutBound) | 60 | 1:57:59 |
| | NAC to Gagalphedi (Return) | 90 | 2:16:00 |
| 70 | NAC to kapan (OutBound) | 10 | 1:05:05 |
| | NAC to kapan (Return) | 10 | 0:49:12 |
| 71 | NAC to Milanchowk (OutBound) | 5 | 0:38:56 |
| | NAC to Milanchowk (Return) | 10 | 1:02:47 |
| 72 | NAC-Goldhunga (OutBound) | 10 | 0:41:55 |
| | NAC-Goldhunga (Return) | 10 | 0:59:16 |
| 73 | NAC-Jitpur Phedi (OutBound) | 10 | 1:13:44 |
| | NAC-Jitpur Phedi (Return) | 10 | 1:16:40 |
| 74 | NAC-Nakkhipot (OutBound) | 5 | 0:55:07 |
| | NAC-Nakkhipot (Return) | 10 | 0:45:56 |
| 75 | NAC-Sundar Basti (OutBound) | 10 | 0:35:29 |
| | NAC-Sundar Basti (Return) | 10 | 1:00:56 |
| 76 | NAC(Ratnapark) to Thankot (checkpost) (OutBound) | 2 | 1:03:07 |
| | NAC(Ratnapark) to Thankot (checkpost) (Return) | 3 | 1:08:33 |
| 77 | NagdhungaKalanki NAC(Ratnapark) (OutBound) | 7 | 1:04:05 |
| | NagdhungaKalanki NAC(Ratnapark) (Return) | 10 | 1:05:42 |
| 78 | Narayanthan to Nagdhunga (OutBound) | 10 | 1:39:38 |
| | Narayanthan to Nagdhunga (Return) | 10 | 1:47:28 |
| 79 | Nayabuspark Banepa Dhulikhel (OutBound) | 5 | 2:33:18 |
| | Nayabuspark Banepa Dhulikhel (Return) | 5 | 2:42:49 |

| | | | |
|---|---|---|---|
| 80 | NayaBuspark Gongabu Lainchaur Ghantaghar Putalisadak Hattisar Maitidevi Purano Baneshowr Sinamangal (OutBound) | 10 | 1:04:51 |
| | NayaBuspark Gongabu Lainchaur Ghantaghar Putalisadak Hattisar Maitidevi Purano Baneshowr Sinamangal (Return) | 10 | 1:07:21 |
| 81 | Pandeychhap-Taudaha-Balkhu-Kalimati-NAC (OutBound) | 15 | 0:51:55 |
| | Pandeychhap-Taudaha-Balkhu-Kalimati-NAC (Return) | 15 | 0:45:46 |
| 82 | Panga-Balkhu-Kalimati-NAC (OutBound) | 10 | 0:33:18 |
| | Panga-Balkhu-Kalimati-NAC (Return) | 8 | 1:22:15 |
| 83 | Payutar NAC(Ratnapark) (OutBound) | 10 | 0:55:25 |
| | Payutar NAC(Ratnapark) (Return) | 10 | 0:58:52 |
| 84 | Pushpalal (Champadevi) Buspark-Kirtipur-Balkhu-Kalimati-NAC (OutBound) | 10 | 1:54:47 |
| | Pushpalal (Champadevi) Buspark-Kirtipur-Balkhu-Kalimati-NAC (Return) | 10 | 1:18:05 |
| 85 | radhe radhe to NAC(Ratnapark) (OutBound) | 15 | 0:59:24 |
| | radhe radhe to NAC(Ratnapark) (Return) | 15 | 1:00:18 |
| 86 | Ramkot Sitapaila Swoyambhu Dallu Nayabazar NAC(Ratnapark) (OutBound) | 10 | 1:42:53 |
| | Ramkot Sitapaila Swoyambhu Dallu Nayabazar NAC(Ratnapark) (Return) | 10 | 0:58:05 |
| 87 | Rammandir Kalopul Nilopul Dillibazar Ratnapark (New Road Gate) (OutBound) | 7 | 0:53:42 |
| | Rammandir Kalopul Nilopul Dillibazar Ratnapark (New Road Gate) (Return) | 7 | 1:05:45 |
| 88 | Raniban Banasthali Balaju Nayabazar Kesharmahal NAC(Ratnapark) (OutBound) | 5 | 0:46:34 |
| | Raniban Banasthali Balaju Nayabazar Kesharmahal NAC(Ratnapark) (Return) | 5 | 0:48:24 |
| 89 | Ranipauwa-Kakani-Tinpiple-Bypass (Machhapokhari) (OutBound) | 60 | 2:09:44 |
| | Ranipauwa-Kakani-Tinpiple-Bypass (Machhapokhari) (Return) | 60 | 2:07:27 |
| 90 | Ratnapark Bagbazar - ChanguNarayan Temple (OutBound) | 30 | 2:08:38 |
| | Ratnapark Bagbazar - ChanguNarayan Temple (Return) | 30 | 1:14:36 |
| 91 | Ratnapark Bhrikutimandap Putalisadak Anamnagar NayaBaneshwor PuranoBaneshwor Kalopul (OutBound) | 4 | 0:34:25 |
| | Ratnapark Bhrikutimandap Putalisadak Anamnagar NayaBaneshwor PuranoBaneshwor Kalopul (Return) | 2 | 0:42:25 |
| 92 | Ratnapark tempo park Teku Kalimati Paropakar Chhauni Swoyambhu (Bhagwan pau ) (OutBound) | 3 | 0:29:15 |
| | Ratnapark tempo park Teku Kalimati Paropakar Chhauni Swoyambhu (Bhagwan pau ) (Return) | 2 | 0:36:55 |

| | | | |
|---|---|---|---|
| 93 | Ratnapark tempo park to Kapan (OutBound) | 8 | 1:00:42 |
| | Ratnapark tempo park to Kapan (Return) | 7 | 1:05:37 |
| 94 | Ratnapark tempo park to Kareshwor (OutBound) | 2 | 0:35:21 |
| | Ratnapark tempo park to Kareshwor (Return) | 3 | 0:33:35 |
| 95 | Ratnapark Tempopark to Sinamangal (OutBound) | 8 | 0:32:09 |
| | Ratnapark Tempopark to Sinamangal (Return) | 5 | 0:41:18 |
| 96 | Ratnapark to Budhhapark(Macchegaun) (OutBound) | 10 | 1:13:59 |
| | Ratnapark to Budhhapark(Macchegaun) (Return) | 15 | 0:47:07 |
| 97 | Ratnapark to Chunikhel (OutBound) | 10 | 0:50:08 |
| | Ratnapark to Chunikhel (Return) | 40 | 1:45:53 |
| 98 | Ratnapark to Force Park Kadhaghari(Bus Park) (OutBound) | 5 | 0:59:59 |
| | Ratnapark to Force Park Kadhaghari(Bus Park) (Return) | 4 | 0:46:53 |
| 99 | Ratnapark to Gongabu Naya Buspark (via Teaching) (OutBound) | 10 | 0:46:29 |
| | Ratnapark to Gongabu Naya Buspark (via Teaching) (Return) | 10 | 0:55:22 |
| 100 | Ratnapark to Narayanthan (OutBound) | 4 | 0:51:19 |
| | Ratnapark to Narayanthan (Return) | 5 | 0:52:25 |
| 101 | Ratnapark to Suryadarsan height (OutBound) | 10 | 0:40:44 |
| | Ratnapark to Suryadarsan height (Return) | 10 | 0:28:13 |
| 102 | Ratnapark(Birhospital) Dhulikhel (OutBound) | 5 | 2:02:04 |
| | Ratnapark(Birhospital) Dhulikhel (Return) | 5 | 2:12:42 |
| 103 | Ratnapark(Birhospital) to panauti (OutBound) | 10 | 1:57:05 |
| | Ratnapark(Birhospital) to panauti (Return) | 10 | 2:03:57 |
| 104 | Ratnapark(NAC) to Hasantar (OutBound) | 15 | 1:15:16 |
| | Ratnapark(NAC) to Hasantar (Return) | 15 | 1:13:37 |
| 105 | Ratnapark(NAC) to Jorpati (OutBound) | 10 | 0:52:56 |
| | Ratnapark(NAC) to Jorpati (Return) | 10 | 0:55:41 |
| 106 | Ratnapark(NAC) to Mulpani (OutBound) | 10 | 1:01:57 |
| | Ratnapark(NAC) to Mulpani (Return) | 10 | 1:38:10 |
| 107 | Ratnapark(NAC) to Sankhadevi (OutBound) | 10 | 1:14:31 |
| | Ratnapark(NAC) to Sankhadevi (Return) | 10 | 1:10:45 |
| 108 | Ratnapark(NAC) to Sankhu (OutBound) | 10 | 1:25:21 |
| | Ratnapark(NAC) to Sankhu (Return) | 10 | 1:35:20 |
| 109 | Ratnapark/Newroad gate-Imadol Tempo Park (OutBound) | 10 | 0:39:24 |
| | Ratnapark/Newroad gate-Imadol Tempo Park (Return) | 10 | 0:41:34 |
| 110 | Ringroad Circulation | 3 | 2:29:57 |
| 111 | Sanagaun Koteshwor Baneshwor NAC(Ratnapark) (OutBound) | 8 | 0:50:11 |
| | Sanagaun Koteshwor Baneshwor NAC(Ratnapark) (Return) | 8 | 1:05:25 |
| 112 | Sankhamul Baneshowr Anamnagar Putalisadak Bhrikutimandap Ratnapark (OutBound) | 10 | 0:22:44 |

| | | | |
|---|---|---|---|
| | Sankhamul Baneshowr Anamnagar Putalisadak Bhrikutimandap Ratnapark (Return) | 10 | 0:31:39 |
| 113 | Saraswatikhel-Nilbarahi-Kotweshwor-Bagbazaar (OutBound) | 15 | 1:19:22 |
| | Saraswatikhel-Nilbarahi-Kotweshwor-Bagbazaar (Return) | 15 | 0:52:31 |
| 114 | Shankhamul to jorpati (OutBound) | 2 | 0:49:05 |
| | Shankhamul to jorpati (Return) | 2 | 0:50:50 |
| 115 | Shova bhagwati Kalimati Balkhu satdobato Gwarko Koteshwor Sinamangal Puranobaneshwor Mitidevi Ratnapark Jamal Lainchaur Thamel Sorakhutte Shova bhagwati | 15 | 1:48:12 |
| 116 | Shova bhagwati to Shova bhagwati | 10 | 2:09:05 |
| 117 | Sitapaila Kalimati Teku Ratnapark(New Road Gate) (OutBound) | 10 | 0:39:58 |
| | Sitapaila Kalimati Teku Ratnapark(New Road Gate) (Return) | 7 | 0:48:45 |
| 118 | Sundarighat-Balkhu-Kalanki-Gongabu-Maharajgunj-Teaching Hospital-Lainchaur-NAC (OutBound) | 10 | 1:27:41 |
| | Sundarighat-Balkhu-Kalanki-Gongabu-Maharajgunj-Teaching Hospital-Lainchaur-NAC (Return) | 10 | 1:32:14 |
| 119 | Sundarijal Buspark-Jorpati-Chabahil-Gausala-Bagbazar-NAC (OutBound) | 15 | 1:33:27 |
| | Sundarijal Buspark-Jorpati-Chabahil-Gausala-Bagbazar-NAC (Return) | 15 | 1:24:20 |
| 120 | Tarkeshowr 4 Ward Office NAC(Ratnapark) (OutBound) | 5 | 0:33:54 |
| | Tarkeshowr 4 Ward Office NAC(Ratnapark) (Return) | 5 | 0:25:58 |
| 121 | Taudol-Bohratar-Banasthali-Balaju-Lainchaur-NAC (OutBound) | 18 | 0:49:27 |
| | Taudol-Bohratar-Banasthali-Balaju-Lainchaur-NAC (Return) | 18 | 0:30:26 |
| 122 | Thali Chabhil Balaju Kalanki Naikap (OutBound) | 6 | 2:28:20 |
| | Thali Chabhil Balaju Kalanki Naikap (Return) | 6 | 1:53:08 |
| 123 | Thali Mulpani Airport back Pepsikola Koteshowr Baneshowr Singhadurbar Putalisadak Ghantaghar Sahidgate Tripureshowr Thapathali Maitighar Babarmahal Baneshowr Koteshowr Thali | 7 | 2:11:12 |
| 124 | Thankot to NAC(Ratnapark) (OutBound) | 3 | 0:52:09 |
| | Thankot to NAC(Ratnapark) (Return) | 3 | 0:56:39 |
| 125 | Thankot Tripureshwor Ratnapark Baneshwor Airport (OutBound) | 10 | 1:18:43 |
| | Thankot Tripureshwor Ratnapark Baneshwor Airport (Return) | 10 | 1:23:42 |
| 126 | Thimi Baneshwor NAC(Ratnapark) (OutBound) | 2 | 1:11:18 |
| | Thimi Baneshwor NAC(Ratnapark) (Return) | 2 | 0:44:33 |
| 127 | Thimi Gamcha Tarkhagal (OutBound) | 20 | 0:23:29 |

| | | | |
|---|---|---|---|
| | Thimi Gamcha Tarkhagal (Return) | 20 | 0:29:34 |
| 128 | Thimi Gamcha Tarkhagal (OutBound) | 30 | 0:32:29 |
| | Thimi Gamcha Tarkhagal (Return) | 30 | 0:28:23 |
| 129 | Tinpiple Ratnapark (OutBound) | 10 | 0:58:14 |
| | Tinpiple Ratnapark (Return) | 10 | 1:25:33 |
| 130 | Tokha Sangla Bhatkeko Pul NAC(Ratnapark) (OutBound) | 10 | 1:04:50 |
| | Tokha Sangla Bhatkeko Pul NAC(Ratnapark) (Return) | 10 | 1:00:31 |
| 131 | Tokha(Bishnumati) Sangla Bhatkeko Pul NAC (OutBound) | 9 | 1:09:03 |
| | Tokha(Bishnumati) Sangla Bhatkeko Pul NAC (Return) | 9 | 1:10:36 |
| 132 | Tokha(Chandeshwori) Grande samakhusi NAC (OutBound) | 10 | 1:10:51 |
| | Tokha(Chandeshwori) Grande samakhusi NAC (Return) | 10 | 0:49:27 |
| 133 | Tokha(Saraswati) Grande samakhusi NAC (OutBound) | 10 | 0:59:02 |
| | Tokha(Saraswati) Grande samakhusi NAC (Return) | 10 | 1:00:18 |

# ANNEX-II

# Python Code for GTFS Files

The "stop points", "frequency excel file" and "route shapefiles" need to be imported.

```
import os
import pandas as pd
import geopandas as gpd
import json
from datetime import datetime, timezone, timedelta

def parse_time(timestamp):
    if not timestamp:
        return ""
    try:
        dt = datetime.strptime(timestamp, "%Y-%m-%dT%H:%M:%S%z")
    except ValueError:
        dt = datetime.strptime(timestamp, "%Y-%m-%dT%H:%M:%S.%fZ")
        dt = dt.replace(tzinfo=timezone.utc)

    # Convert to Nepal Standard Time (UTC+5:45)
    dt_nst = dt.astimezone(timezone(timedelta(hours=5, minutes=45)))
    return dt_nst.strftime("%H:%M:%S")

def process_geojson(geojson_folder, excel_file):
    stops_data = []
    stop_times_data = []
    routes_data = []
    trips_data = []
    ridership_data = []

    stop_groups = {}

    df_routes = pd.read_excel(excel_file)
    route_info = df_routes.set_index("route_id")[['route_name_short', 'route_name_long',
'mode']].to_dict(orient='index')

    for file in os.listdir(geojson_folder):
        if file.endswith(".geojson"):
            with open(os.path.join(geojson_folder, file)) as f:
                data = json.load(f)

            points = [f for f in data['features'] if f['geometry']['type'] == 'Point']
            lines = [f for f in data['features'] if f['geometry']['type'] == 'MultiLineString']
```

```
        for point in points:
            props = point['properties']
            stop_id = props['id']
            stop_name = props['name']
            lat, lon = point['geometry']['coordinates'][1], point['geometry']['coordinates'][0]
            board = props.get('board', 0)
            alight = props.get('alight', 0)
            arrival_time = parse_time(props.get('created_at', ''))
            departure_time = parse_time(props.get('updated_at', ''))

            if stop_name not in stop_groups:
                stop_groups[stop_name] = {
                    'parent_id': len(stop_groups) + 20001,
                    'stops': [],
                    'total_boardings': 0,
                    'total_alightings': 0
                }

            stop_groups[stop_name]['stops'].append([id, stop_name, lat, lon, board, alight])

            stop_times_data.append([props['onboard_instance_id'], stop_id, arrival_time,
departure_time, len(stop_times_data) + 1])
            ridership_data.append([props['onboard_instance_id'], stop_id, board, alight])

        for line in lines:
            props = line['properties']
            route_id = props['id']
            route_details = route_info.get(route_id, {"short": "", "long": "", "mode": ""})
            routes_data.append([
                route_id, route_details['route_name_short'],
route_details['route_name_long'], route_details['mode'], ""
            ])
            trips_data.append([route_id, 1, route_id, route_id])

    stops_with_parents = []
    for stop_name, data in stop_groups.items():
        parent_id = data['parent_id']
        num_lines = len(data['stops'])
        stops_with_parents.append([parent_id, stop_name, data['stops'][0][2],
data['stops'][0][3], data['total_boardings'], data['total_alightings'], ""])

def process_shapefiles(shapefile_folder):
    shapes_data = []
    for file in os.listdir(shapefile_folder):
        if file.endswith(".shp"):
            gdf = gpd.read_file(os.path.join(shapefile_folder, file))
            for _, row in gdf.iterrows():
                shape_id = row['id']
                if row.geometry.geom_type == "MultiLineString":
                    for line in row.geometry.geoms:
```

```
                for i, coord in enumerate(line.coords):
                    shapes_data.append([shape_id, coord[1], coord[0], i])
        elif row.geometry.geom_type == "LineString":
            for i, coord in enumerate(row.geometry.coords):
                shapes_data.append([shape_id, coord[1], coord[0], i])
    return shapes_data

def process_frequency(excel_file):
    df = pd.read_excel(excel_file)
    df['headway_secs'] = df['frequency'] * 60
    df['start_time'] = "07:00:00"
    df['end_time'] = "20:00:00"
    return df[['route_id', 'headway_secs', 'start_time', 'end_time']].values.tolist()

def write_gtfs_files(output_folder, stops, stop_times, routes, trips, ridership, shapes,
frequencies):
    os.makedirs(output_folder, exist_ok=True)
    pd.DataFrame(stops, columns=["stop_id", "stop_name", "stop_lat", "stop_lon",
"boardings", "alightings", "parent_station"]).to_csv(f"{output_folder}/stops.txt",
index=False)
    pd.DataFrame(stop_times, columns=["trip_id", "stop_id", "arrival_time",
"departure_time", "stop_sequence"]).to_csv(f"{output_folder}/stop_times.txt",
index=False)
    pd.DataFrame(routes, columns=["route_id", "route_short_name", "route_long_name",
"route_type", "agency_id"]).to_csv(f"{output_folder}/routes.txt", index=False)
    pd.DataFrame(trips, columns=["route_id", "service_id", "trip_id",
"shape_id"]).to_csv(f"{output_folder}/trips.txt", index=False)
    pd.DataFrame(ridership, columns=["trip_id", "stop_id", "boardings",
"alightings"]).to_csv(f"{output_folder}/ridership.txt", index=False)
    pd.DataFrame(shapes, columns=["shape_id", "shape_pt_lat", "shape_pt_lon",
"shape_pt_sequence"]).to_csv(f"{output_folder}/shapes.txt", index=False)
    pd.DataFrame(frequencies, columns=["trip_id", "headway_secs", "start_time",
"end_time"]).to_csv(f"{output_folder}/frequencies.txt", index=False)

def main(geojson_folder, shapefile_folder, excel_file, output_folder):
    stops, stop_times, routes, trips, ridership = process_geojson(geojson_folder, excel_file)
    shapes = process_shapefiles(shapefile_folder)
    frequencies = process_frequency(excel_file)
    write_gtfs_files(output_folder, stops, stop_times, routes, trips, ridership, shapes,
frequencies)

main("stop points", "shapefiles", "frequency excel file", "GTFS files"
```

# ANNEX-III

## Python Code for k medoids clustering, elbow plot

```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
from sklearn_extra.cluster import KMedoids
from sklearn.metrics import silhouette_score

file_path = r"travel time excel"

df = pd.read_excel(file_path, header=None)

travel_times = df.values.flatten()

travel_times = np.array([x for x in tqdm(travel_times, desc="Filtering") if not
np.isnan(x)])

sample_size = min(5000, len(travel_times))

sampled_data = shuffle(travel_times, random_state=42)[:sample_size].reshape(-1, 1)

inertia_values = []
K_range = range(2, 10)  # Trying clusters from 2 to 10

for k in tqdm(K_range, desc="Computing Inertia"):
    kmedoids = KMedoids(n_clusters=k, random_state=42, metric="euclidean")
    kmedoids.fit(sampled_data)
    inertia_values.append(kmedoids.inertia_)

plt.figure(figsize=(8, 5))
plt.plot(K_range, inertia_values, marker='o', linestyle='-', color='b')
plt.xlabel("Number of Clusters (k)")
plt.ylabel("Inertia (Sum of Distances to Medoids)")
plt.title("Elbow Method for Optimal K")
plt.xticks(K_range)
plt.grid()
plt.show()

optimal_k = int(input("Enter the optimal number of clusters based on the elbow plot: "))
kmedoids = KMedoids(n_clusters=optimal_k, random_state=42, metric="euclidean")
kmedoids.fit(sampled_data)
```

```
labels = np.array([kmedoids.predict([[x]])[0] for x in tqdm(travel_times, desc="Predicting
Clusters")])

cluster_ranges = {}
cluster_counts = {}

for i in tqdm(range(optimal_k), desc="Computing Statistics"):
    cluster_points = travel_times[labels == i]
    cluster_ranges[i] = (np.min(cluster_points), np.max(cluster_points))
    cluster_counts[i] = len(cluster_points)
    print(f"  - Cluster {i}: Range = {cluster_ranges[i]}, Count = {cluster_counts[i]}")


plt.figure(figsize=(10, 5))
plt.scatter(travel_times, travel_times, c=remapped_labels, cmap='viridis', alpha=0.7)
plt.xlabel("Travel Time (X)")
plt.ylabel("Travel Time (Y)")
plt.title(f"K-Medoids Clustering with k={optimal_k} (ID 5 = Shortest, ID 0 = Longest)")
plt.colorbar(label="Cluster ID")
plt.grid()
plt.show()

silhouette_values = silhouette_samples(sampled_data, kmedoids.labels_)

plt.figure(figsize=(8, 5))
y_lower, y_upper = 0, 0
for i in range(optimal_k):
    ith_silhouette_values = silhouette_values[kmedoids.labels_ == i]
    ith_silhouette_values.sort()

    ith_silhouette_values = np.maximum(ith_silhouette_values, 0)

plt.axvline(x=np.mean(silhouette_values[silhouette_values > 0]), color="red",
linestyle="--", label="Avg Silhouette Score")
plt.xlabel("Silhouette Coefficient")
plt.ylabel("Cluster")
plt.title("Silhouette Plot for K-Medoids Clusters")
plt.legend()
plt.grid()
plt.show()
```

# ANNEX-IV

## Ward wise accessibility scores

| Zone Number | Zone Name | Health | Education | Work | PTWAI |
|---|---|---|---|---|---|
| 250101 | LalitpurBagmati1 | 0.000 | 0.001 | 0.981 | 0.981 |
| 250102 | LalitpurBagmati2 | 0.000 | 0 | 0.002 | 0.002 |
| 250103 | LalitpurBagmati3 | 0.071 | 0.001 | 0.964 | 1.035 |
| 250104 | LalitpurBagmati4 | 0.071 | 0 | 0.004 | 0.075 |
| 250105 | LalitpurBagmati5 | 0.000 | 0.001 | 0.004 | 0.004 |
| 250106 | LalitpurBagmati6 | 0.000 | 0.001 | 0.004 | 0.004 |
| 250107 | LalitpurBagmati7 | 0.000 | 0 | 0.002 | 0.002 |
| 250201 | LalitpurGodawari1 | 2.829 | 2.851 | 3.019 | 8.698 |
| 250202 | LalitpurGodawari2 | 1.786 | 1.935 | 2.413 | 6.134 |
| 250203 | LalitpurGodawari3 | 2.564 | 2.606 | 2.951 | 8.121 |
| 250204 | LalitpurGodawari4 | 2.764 | 3.247 | 2.846 | 8.858 |
| 250205 | LalitpurGodawari5 | 0.971 | 0.788 | 1.713 | 3.473 |
| 250206 | LalitpurGodawari6 | 0.179 | 0.074 | 0.993 | 1.246 |
| 250207 | LalitpurGodawari7 | 0.014 | 0.004 | 0.991 | 1.009 |
| 250208 | LalitpurGodawari8 | 0.350 | 0.180 | 0.992 | 1.522 |
| 250209 | LalitpurGodawari9 | 2.200 | 2.132 | 2.527 | 6.859 |
| 250210 | LalitpurGodawari10 | 1.307 | 1.290 | 1.931 | 4.528 |
| 250211 | LalitpurGodawari11 | 2.400 | 2.233 | 2.678 | 7.311 |
| 250212 | LalitpurGodawari12 | 3.050 | 3.285 | 3.297 | 9.632 |
| 250213 | LalitpurGodawari13 | 1.900 | 2.089 | 2.673 | 6.662 |
| 250214 | LalitpurGodawari14 | 3.314 | 3.573 | 3.57 | 10.457 |
| 250301 | LalitpurKonjyosom1 | 0.014 | 0.000 | 0.781 | 0.795 |
| 250302 | LalitpurKonjyosom2 | 0.000 | 0.000 | 0.005 | 0.005 |
| 250303 | LalitpurKonjyosom3 | 0.000 | 0.000 | 0.872 | 0.872 |
| 250304 | LalitpurKonjyosom4 | 0.021 | 0.004 | 0.993 | 1.018 |
| 250305 | LalitpurKonjyosom5 | 0.000 | 0.001 | 0.852 | 0.853 |
| 250401 | LalitpurLalitpur1 | 3.929 | 4.307 | 4.089 | 12.324 |
| 250402 | LalitpurLalitpur2 | 3.943 | 4.284 | 4.094 | 12.321 |
| 250403 | LalitpurLalitpur3 | 3.779 | 4.119 | 4.002 | 11.900 |
| 250404 | LalitpurLalitpur4 | 3.943 | 4.287 | 4.192 | 12.422 |
| 250405 | LalitpurLalitpur5 | 3.729 | 3.967 | 3.864 | 11.560 |
| 250406 | LalitpurLalitpur6 | 3.900 | 4.123 | 3.983 | 12.006 |
| 250407 | LalitpurLalitpur7 | 3.993 | 4.281 | 4.12 | 12.394 |
| 250408 | LalitpurLalitpur8 | 4.079 | 4.432 | 4.25 | 12.760 |
| 250409 | LalitpurLalitpur9 | 3.979 | 4.308 | 4.151 | 12.438 |
| 250410 | LalitpurLalitpur10 | 3.850 | 4.302 | 4.048 | 12.200 |
| 250411 | LalitpurLalitpur11 | 3.586 | 3.878 | 3.705 | 11.169 |
| 250412 | LalitpurLalitpur12 | 4.000 | 4.289 | 4.137 | 12.426 |

| | | | | | |
|---|---|---|---|---|---|
| 250413 | LalitpurLalitpur13 | 3.821 | 4.047 | 3.983 | 11.852 |
| 250414 | LalitpurLalitpur14 | 3.571 | 4.183 | 3.857 | 11.611 |
| 250415 | LalitpurLalitpur15 | 3.386 | 3.893 | 3.672 | 10.951 |
| 250416 | LalitpurLalitpur16 | 3.929 | 4.208 | 4.076 | 12.212 |
| 250417 | LalitpurLalitpur17 | 3.300 | 3.933 | 3.736 | 10.969 |
| 250418 | LalitpurLalitpur18 | 3.450 | 3.515 | 3.539 | 10.504 |
| 250419 | LalitpurLalitpur19 | 4.100 | 4.592 | 4.319 | 13.011 |
| 250420 | LalitpurLalitpur20 | 3.993 | 4.268 | 4.111 | 12.372 |
| 250421 | LalitpurLalitpur21 | 1.664 | 1.642 | 2.141 | 5.447 |
| 250422 | LalitpurLalitpur22 | 1.571 | 1.594 | 2.089 | 5.254 |
| 250423 | LalitpurLalitpur23 | 2.693 | 3.063 | 3.085 | 8.841 |
| 250424 | LalitpurLalitpur24 | 3.136 | 3.353 | 3.298 | 9.787 |
| 250425 | LalitpurLalitpur25 | 3.357 | 3.816 | 3.609 | 10.782 |
| 250426 | LalitpurLalitpur26 | 3.293 | 3.630 | 3.423 | 10.346 |
| 250427 | LalitpurLalitpur27 | 3.264 | 3.597 | 3.412 | 10.274 |
| 250428 | LalitpurLalitpur28 | 3.050 | 3.394 | 3.336 | 9.780 |
| 250429 | LalitpurLalitpur29 | 3.014 | 3.328 | 3.303 | 9.646 |
| 250501 | LalitpurMahalaxmi1 | 3.471 | 4.000 | 3.665 | 11.136 |
| 250502 | LalitpurMahalaxmi2 | 3.986 | 4.361 | 4.193 | 12.540 |
| 250503 | LalitpurMahalaxmi3 | 3.529 | 3.807 | 3.684 | 11.020 |
| 250504 | LalitpurMahalaxmi4 | 3.086 | 3.257 | 3.219 | 9.562 |
| 250505 | LalitpurMahalaxmi5 | 2.957 | 3.222 | 3.138 | 9.317 |
| 250506 | LalitpurMahalaxmi6 | 2.879 | 3.140 | 3.153 | 9.171 |
| 250507 | LalitpurMahalaxmi7 | 2.550 | 2.590 | 3.214 | 8.354 |
| 250508 | LalitpurMahalaxmi8 | 2.757 | 3.107 | 3.11 | 8.975 |
| 250509 | LalitpurMahalaxmi9 | 2.150 | 2.189 | 2.673 | 7.012 |
| 250510 | LalitpurMahalaxmi10 | 0.264 | 0.063 | 0.991 | 1.318 |
| 250601 | LalitpurMahankal1 | 0.000 | 0.000 | 0.003 | 0.003 |
| 250602 | LalitpurMahankal2 | 0.071 | 0.000 | 0.011 | 0.082 |
| 250603 | LalitpurMahankal3 | 0.014 | 0.000 | 0.009 | 0.023 |
| 250604 | LalitpurMahankal4 | 0.000 | 0.000 | 0.008 | 0.008 |
| 250605 | LalitpurMahankal5 | 0.000 | 0.000 | 0.027 | 0.027 |
| 250606 | LalitpurMahankal6 | 0.000 | 0.000 | 0.006 | 0.006 |
| 260101 | BhaktapurBhaktapur1 | 3.393 | 3.840 | 3.584 | 10.817 |
| 260102 | BhaktapurBhaktapur2 | 3.486 | 3.531 | 3.625 | 10.641 |
| 260103 | BhaktapurBhaktapur3 | 3.586 | 3.613 | 3.743 | 10.942 |
| 260104 | BhaktapurBhaktapur4 | 2.543 | 2.999 | 3.013 | 8.555 |
| 260105 | BhaktapurBhaktapur5 | 3.493 | 3.552 | 3.629 | 10.674 |
| 260106 | BhaktapurBhaktapur6 | 3.493 | 3.630 | 3.708 | 10.831 |
| 260107 | BhaktapurBhaktapur7 | 3.471 | 3.506 | 3.525 | 10.502 |
| 260108 | BhaktapurBhaktapur8 | 3.107 | 3.341 | 3.271 | 9.719 |
| 260109 | BhaktapurBhaktapur9 | 3.136 | 3.293 | 3.242 | 9.671 |
| 260110 | BhaktapurBhaktapur10 | 3.329 | 3.754 | 3.5 | 10.583 |
| 260201 | BhaktapurChangunarayan1 | 1.821 | 1.919 | 2.531 | 6.271 |
| 260202 | BhaktapurChangunarayan2 | 2.107 | 2.099 | 2.728 | 6.934 |
| 260203 | BhaktapurChangunarayan3 | 1.771 | 1.908 | 2.279 | 5.959 |
| 260204 | BhaktapurChangunarayan4 | 1.764 | 1.719 | 2.265 | 5.748 |
| 260205 | BhaktapurChangunarayan5 | 1.143 | 1.065 | 1.928 | 4.136 |

| | | | | | |
|---|---|---|---|---|---|
| 260206 | BhaktapurChangunarayan6 | 2.186 | 2.324 | 2.776 | 7.285 |
| 260207 | BhaktapurChangunarayan7 | 3.186 | 3.415 | 2.868 | 9.469 |
| 260208 | BhaktapurChangunarayan8 | 3.036 | 3.213 | 2.854 | 9.103 |
| 260209 | BhaktapurChangunarayan9 | 1.036 | 1.012 | 1.869 | 3.916 |
| 260301 | BhaktapurMadhyapur Thimi1 | 3.786 | 3.788 | 3.669 | 11.243 |
| 260302 | BhaktapurMadhyapur Thimi2 | 3.493 | 3.820 | 3.557 | 10.870 |
| 260303 | BhaktapurMadhyapur Thimi3 | 3.786 | 4.067 | 3.979 | 11.832 |
| 260304 | BhaktapurMadhyapur Thimi4 | 3.150 | 3.306 | 3.281 | 9.737 |
| 260305 | BhaktapurMadhyapur Thimi5 | 3.114 | 3.416 | 3.35 | 9.880 |
| 260306 | BhaktapurMadhyapur Thimi6 | 3.036 | 3.288 | 3.262 | 9.585 |
| 260307 | BhaktapurMadhyapur Thimi7 | 3.236 | 3.380 | 3.302 | 9.918 |
| 260308 | BhaktapurMadhyapur Thimi8 | 3.179 | 3.402 | 3.41 | 9.990 |
| 260309 | BhaktapurMadhyapur Thimi9 | 2.864 | 3.074 | 3.106 | 9.045 |
| 260401 | BhaktapurSuryabinayak1 | 3.457 | 3.541 | 3.61 | 10.608 |
| 260402 | BhaktapurSuryabinayak2 | 2.571 | 2.561 | 3.18 | 8.312 |
| 260403 | BhaktapurSuryabinayak3 | 2.821 | 2.864 | 3.033 | 8.719 |
| 260404 | BhaktapurSuryabinayak4 | 2.507 | 2.506 | 3.429 | 8.443 |
| 260405 | BhaktapurSuryabinayak5 | 3.107 | 3.230 | 3.214 | 9.551 |
| 260406 | BhaktapurSuryabinayak6 | 2.964 | 3.113 | 3.15 | 9.227 |
| 260407 | BhaktapurSuryabinayak7 | 0.950 | 0.990 | 1.837 | 3.777 |
| 260408 | BhaktapurSuryabinayak8 | 3.179 | 3.566 | 3.415 | 10.159 |
| 260409 | BhaktapurSuryabinayak9 | 2.700 | 2.733 | 2.999 | 8.432 |
| 260410 | BhaktapurSuryabinayak10 | 2.264 | 2.342 | 2.775 | 7.381 |
| 270101 | KathmanduBudhanilakantha1 | 1.664 | 1.905 | 2.282 | 5.851 |
| 270102 | KathmanduBudhanilakantha2 | 2.000 | 2.134 | 2.474 | 6.608 |
| 270103 | KathmanduBudhanilakantha3 | 1.450 | 1.534 | 2.115 | 5.099 |
| 270104 | KathmanduBudhanilakantha4 | 2.914 | 2.960 | 3.147 | 9.021 |
| 270105 | KathmanduBudhanilakantha5 | 1.664 | 1.871 | 2.274 | 5.809 |
| 270106 | KathmanduBudhanilakantha6 | 2.993 | 3.156 | 3.176 | 9.325 |
| 270107 | KathmanduBudhanilakantha7 | 3.257 | 3.731 | 3.645 | 10.633 |
| 270108 | KathmanduBudhanilakantha8 | 3.207 | 3.374 | 3.3 | 9.882 |
| 270109 | KathmanduBudhanilakantha9 | 3.586 | 3.854 | 3.759 | 11.199 |
| 270110 | KathmanduBudhanilakantha10 | 3.650 | 3.730 | 3.795 | 11.175 |
| 270111 | KathmanduBudhanilakantha11 | 3.164 | 3.416 | 3.342 | 9.922 |
| 270112 | KathmanduBudhanilakantha12 | 3.557 | 3.705 | 3.736 | 10.999 |
| 270113 | KathmanduBudhanilakantha13 | 1.871 | 1.965 | 2.614 | 6.450 |
| 270201 | KathmanduChandragiri1 | 2.914 | 2.945 | 3.129 | 8.989 |
| 270202 | KathmanduChandragiri2 | 2.407 | 2.428 | 2.839 | 7.675 |
| 270203 | KathmanduChandragiri3 | 2.986 | 3.179 | 3.127 | 9.292 |
| 270204 | KathmanduChandragiri4 | 1.036 | 1.010 | 1.955 | 4.001 |
| 270205 | KathmanduChandragiri5 | 3.786 | 3.889 | 3.934 | 11.608 |
| 270206 | KathmanduChandragiri6 | 2.007 | 2.110 | 2.642 | 6.759 |
| 270207 | KathmanduChandragiri7 | 1.686 | 1.607 | 2.047 | 5.340 |
| 270208 | KathmanduChandragiri8 | 2.336 | 2.499 | 2.878 | 7.713 |
| 270209 | KathmanduChandragiri9 | 2.586 | 2.602 | 2.898 | 8.086 |
| 270210 | KathmanduChandragiri10 | 3.857 | 4.102 | 3.98 | 11.939 |
| 270211 | KathmanduChandragiri11 | 3.750 | 3.982 | 3.855 | 11.587 |
| 270212 | KathmanduChandragiri12 | 2.700 | 2.668 | 2.95 | 8.318 |

| | | | | | |
|---|---|---|---|---|---|
| 270213 | KathmanduChandragiri13 | 3.214 | 3.501 | 3.516 | 10.231 |
| 270214 | KathmanduChandragiri14 | 3.743 | 3.878 | 3.873 | 11.494 |
| 270215 | KathmanduChandragiri15 | 3.593 | 3.927 | 3.783 | 11.303 |
| 270301 | KathmanduDakshinkali1 | 1.000 | 1.006 | 1.952 | 3.958 |
| 270302 | KathmanduDakshinkali2 | 0.671 | 0.681 | 0.997 | 2.349 |
| 270303 | KathmanduDakshinkali3 | 1.750 | 1.884 | 2.243 | 5.877 |
| 270304 | KathmanduDakshinkali4 | 2.050 | 2.198 | 2.733 | 6.981 |
| 270305 | KathmanduDakshinkali5 | 1.986 | 2.105 | 2.688 | 6.779 |
| 270306 | KathmanduDakshinkali6 | 1.950 | 2.022 | 2.602 | 6.574 |
| 270307 | KathmanduDakshinkali7 | 0.186 | 0.190 | 0.993 | 1.369 |
| 270308 | KathmanduDakshinkali8 | 0.900 | 0.964 | 1.009 | 2.873 |
| 270309 | KathmanduDakshinkali9 | 0.900 | 0.964 | 1.01 | 2.874 |
| 270401 | KathmanduGokarneshwor1 | 0.407 | 0.460 | 0.993 | 1.860 |
| 270402 | KathmanduGokarneshwor2 | 1.729 | 1.847 | 2.216 | 5.792 |
| 270403 | KathmanduGokarneshwor3 | 0.357 | 0.325 | 1.003 | 1.685 |
| 270404 | KathmanduGokarneshwor4 | 1.643 | 1.918 | 2.438 | 5.998 |
| 270405 | KathmanduGokarneshwor5 | 3.114 | 3.457 | 3.419 | 9.991 |
| 270406 | KathmanduGokarneshwor6 | 3.150 | 3.679 | 3.465 | 10.294 |
| 270407 | KathmanduGokarneshwor7 | 3.179 | 3.500 | 3.422 | 10.101 |
| 270408 | KathmanduGokarneshwor8 | 3.221 | 3.775 | 3.503 | 10.499 |
| 270409 | KathmanduGokarneshwor9 | 2.400 | 2.927 | 2.957 | 8.284 |
| 270501 | KathmanduKageshwori Manahora1 | 2.000 | 2.036 | 2.468 | 6.504 |
| 270502 | KathmanduKageshwori Manahora2 | 2.014 | 2.098 | 2.575 | 6.688 |
| 270503 | KathmanduKageshwori Manahora3 | 1.621 | 1.569 | 2.1 | 5.290 |
| 270504 | KathmanduKageshwori Manahora4 | 1.593 | 1.958 | 2.153 | 5.704 |
| 270505 | KathmanduKageshwori Manahora5 | 2.307 | 2.740 | 2.857 | 7.904 |
| 270506 | KathmanduKageshwori Manahora6 | 3.250 | 3.801 | 3.513 | 10.564 |
| 270507 | KathmanduKageshwori Manahora7 | 2.871 | 3.129 | 3.172 | 9.172 |
| 270508 | KathmanduKageshwori Manahora8 | 3.221 | 3.465 | 3.505 | 10.192 |
| 270509 | KathmanduKageshwori Manahora9 | 3.450 | 3.508 | 3.522 | 10.480 |
| 270601 | KathmanduKathmandu1 | 3.986 | 4.435 | 4.171 | 12.591 |
| 270602 | KathmanduKathmandu2 | 3.829 | 4.074 | 4.009 | 11.911 |
| 270603 | KathmanduKathmandu3 | 4.029 | 4.234 | 4.095 | 12.358 |
| 270604 | KathmanduKathmandu4 | 3.950 | 4.321 | 4.192 | 12.463 |
| 270605 | KathmanduKathmandu5 | 3.664 | 3.960 | 3.859 | 11.483 |
| 270606 | KathmanduKathmandu6 | 3.500 | 4.081 | 3.778 | 11.359 |
| 270607 | KathmanduKathmandu7 | 3.850 | 4.120 | 3.912 | 11.882 |
| 270608 | KathmanduKathmandu8 | 3.871 | 4.093 | 3.967 | 11.931 |
| 270609 | KathmanduKathmandu9 | 4.014 | 4.249 | 4.052 | 12.315 |
| 270610 | KathmanduKathmandu10 | 4.100 | 4.647 | 4.392 | 13.139 |
| 270611 | KathmanduKathmandu11 | 4.079 | 4.633 | 4.357 | 13.069 |
| 270612 | KathmanduKathmandu12 | 4.229 | 4.399 | 4.303 | 12.931 |
| 270613 | KathmanduKathmandu13 | 4.057 | 4.485 | 4.243 | 12.785 |
| 270614 | KathmanduKathmandu14 | 3.986 | 4.278 | 4.203 | 12.467 |
| 270615 | KathmanduKathmandu15 | 4.107 | 4.451 | 4.323 | 12.881 |
| 270616 | KathmanduKathmandu16 | 3.893 | 4.163 | 4.035 | 12.090 |
| 270617 | KathmanduKathmandu17 | 3.457 | 4.016 | 3.733 | 11.206 |
| 270618 | KathmanduKathmandu18 | 3.679 | 4.203 | 3.919 | 11.801 |

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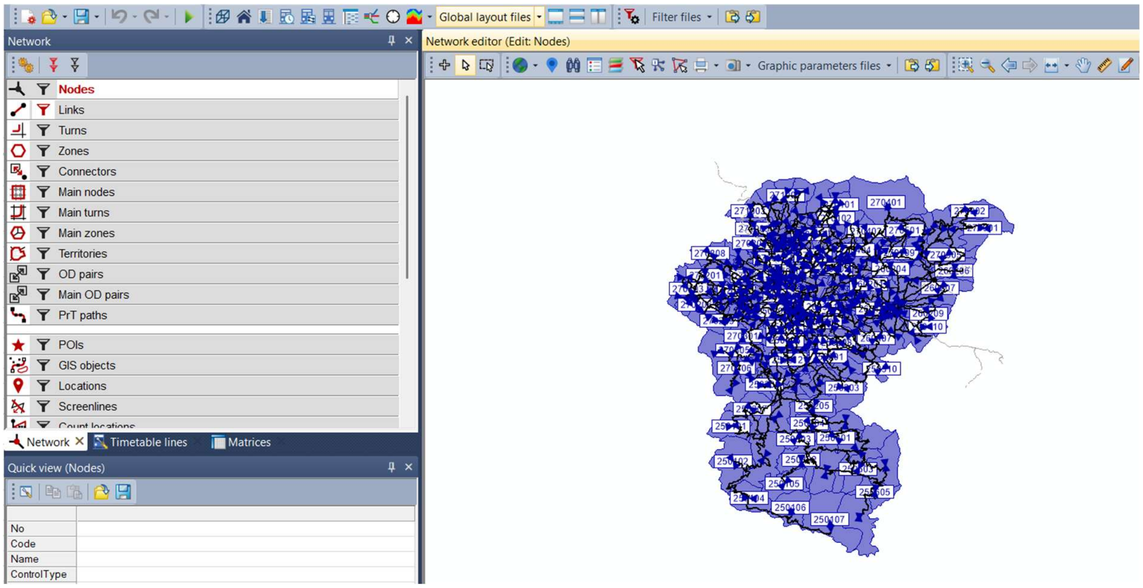
|---|---|---|---|---|---|
| 270619 | KathmanduKathmandu19 | 3.964 | 4.298 | 4.149 | 12.411 |
| 270620 | KathmanduKathmandu20 | 4.050 | 4.358 | 4.205 | 12.613 |
| 270621 | KathmanduKathmandu21 | 3.350 | 3.890 | 3.639 | 10.879 |
| 270622 | KathmanduKathmandu22 | 4.021 | 4.395 | 4.225 | 12.642 |
| 270623 | KathmanduKathmandu23 | 3.757 | 4.051 | 3.885 | 11.693 |
| 270624 | KathmanduKathmandu24 | 3.850 | 3.869 | 3.941 | 11.660 |
| 270625 | KathmanduKathmandu25 | 3.400 | 3.981 | 3.677 | 11.058 |
| 270626 | KathmanduKathmandu26 | 4.043 | 4.355 | 4.265 | 12.663 |
| 270627 | KathmanduKathmandu27 | 3.736 | 4.294 | 4.019 | 12.049 |
| 270628 | KathmanduKathmandu28 | 4.036 | 4.546 | 4.227 | 12.808 |
| 270629 | KathmanduKathmandu29 | 4.000 | 4.408 | 4.134 | 12.542 |
| 270630 | KathmanduKathmandu30 | 3.743 | 4.298 | 3.983 | 12.024 |
| 270631 | KathmanduKathmandu31 | 3.843 | 4.145 | 4.005 | 11.993 |
| 270632 | KathmanduKathmandu32 | 3.779 | 4.128 | 4.038 | 11.945 |
| 270701 | KathmanduKirtipur1 | 3.193 | 3.508 | 3.497 | 10.198 |
| 270702 | KathmanduKirtipur2 | 3.743 | 3.876 | 3.85 | 11.469 |
| 270703 | KathmanduKirtipur3 | 3.536 | 3.893 | 3.683 | 11.111 |
| 270704 | KathmanduKirtipur4 | 3.129 | 3.431 | 3.388 | 9.948 |
| 270705 | KathmanduKirtipur5 | 3.129 | 3.427 | 3.373 | 9.929 |
| 270706 | KathmanduKirtipur6 | 0.936 | 1.000 | 1.453 | 3.389 |
| 270707 | KathmanduKirtipur7 | 3.743 | 3.878 | 3.876 | 11.497 |
| 270708 | KathmanduKirtipur8 | 3.486 | 3.794 | 3.712 | 10.991 |
| 270709 | KathmanduKirtipur9 | 3.664 | 4.193 | 3.897 | 11.754 |
| 270710 | KathmanduKirtipur10 | 3.021 | 3.431 | 3.326 | 9.779 |
| 270801 | KathmanduNagarjun1 | 2.907 | 3.136 | 3.124 | 9.168 |
| 270802 | KathmanduNagarjun2 | 3.721 | 3.777 | 3.762 | 11.260 |
| 270803 | KathmanduNagarjun3 | 1.414 | 1.472 | 1.972 | 4.858 |
| 270804 | KathmanduNagarjun4 | 2.771 | 3.115 | 3.166 | 9.052 |
| 270805 | KathmanduNagarjun5 | 1.771 | 1.859 | 2.335 | 5.965 |
| 270806 | KathmanduNagarjun6 | 2.243 | 2.331 | 2.812 | 7.386 |
| 270807 | KathmanduNagarjun7 | 3.164 | 3.453 | 3.444 | 10.061 |
| 270808 | KathmanduNagarjun8 | 1.593 | 1.849 | 2.277 | 5.719 |
| 270809 | KathmanduNagarjun9 | 3.193 | 3.509 | 3.467 | 10.169 |
| 270810 | KathmanduNagarjun10 | 3.200 | 3.530 | 3.504 | 10.234 |
| 270901 | KathmanduShankharapur1 | 0.000 | 0.000 | 0.978 | 0.978 |
| 270902 | KathmanduShankharapur2 | 0.000 | 0.000 | 0.973 | 0.973 |
| 270903 | KathmanduShankharapur3 | 0.314 | 0.313 | 0.991 | 1.618 |
| 270904 | KathmanduShankharapur4 | 0.000 | 0.001 | 0.991 | 0.992 |
| 270905 | KathmanduShankharapur5 | 0.014 | 0.001 | 0.993 | 1.008 |
| 270906 | KathmanduShankharapur6 | 2.407 | 2.424 | 2.875 | 7.706 |
| 270907 | KathmanduShankharapur7 | 2.264 | 2.395 | 2.806 | 7.465 |
| 270908 | KathmanduShankharapur8 | 0.014 | 0.001 | 0.994 | 1.009 |
| 270909 | KathmanduShankharapur9 | 2.150 | 2.209 | 2.698 | 7.057 |
| 271001 | KathmanduTarakeshwor1 | 2.879 | 2.844 | 3.048 | 8.771 |
| 271002 | KathmanduTarakeshwor2 | 3.221 | 3.855 | 3.589 | 10.666 |
| 271003 | KathmanduTarakeshwor3 | 1.086 | 1.038 | 1.938 | 4.061 |
| 271004 | KathmanduTarakeshwor4 | 3.029 | 3.331 | 3.246 | 9.606 |
| 271005 | KathmanduTarakeshwor5 | 1.700 | 1.835 | 2.275 | 5.810 |

| | | | | | |
|---|---|---|---|---|---|
| 271006 | KathmanduTarakeshwor6 | 3.043 | 3.377 | 3.28 | 9.700 |
| 271007 | KathmanduTarakeshwor7 | 1.750 | 1.931 | 2.397 | 6.078 |
| 271008 | KathmanduTarakeshwor8 | 3.121 | 3.671 | 3.518 | 10.310 |
| 271009 | KathmanduTarakeshwor9 | 3.179 | 3.378 | 3.294 | 9.850 |
| 271010 | KathmanduTarakeshwor10 | 3.329 | 3.470 | 3.469 | 10.267 |
| 271011 | KathmanduTarakeshwor11 | 3.093 | 3.396 | 3.322 | 9.811 |
| 271101 | KathmanduTokha1 | 2.107 | 2.217 | 2.733 | 7.057 |
| 271102 | KathmanduTokha2 | 2.136 | 2.207 | 2.657 | 7.000 |
| 271103 | KathmanduTokha3 | 3.771 | 4.058 | 3.974 | 11.804 |
| 271104 | KathmanduTokha4 | 3.414 | 3.495 | 3.543 | 10.452 |
| 271105 | KathmanduTokha5 | 3.779 | 4.080 | 3.993 | 11.851 |
| 271106 | KathmanduTokha6 | 3.786 | 3.860 | 3.775 | 11.420 |
| 271107 | KathmanduTokha7 | 3.721 | 3.733 | 3.771 | 11.225 |
| 271108 | KathmanduTokha8 | 3.721 | 4.245 | 3.945 | 11.911 |
| 271109 | KathmanduTokha9 | 3.771 | 3.910 | 3.935 | 11.616 |
| 271110 | KathmanduTokha10 | 3.786 | 3.911 | 3.796 | 11.492 |
| 271111 | KathmanduTokha11 | 3.757 | 4.010 | 3.863 | 11.630 |

# ANNEX-V

# PTV Visum Calculation



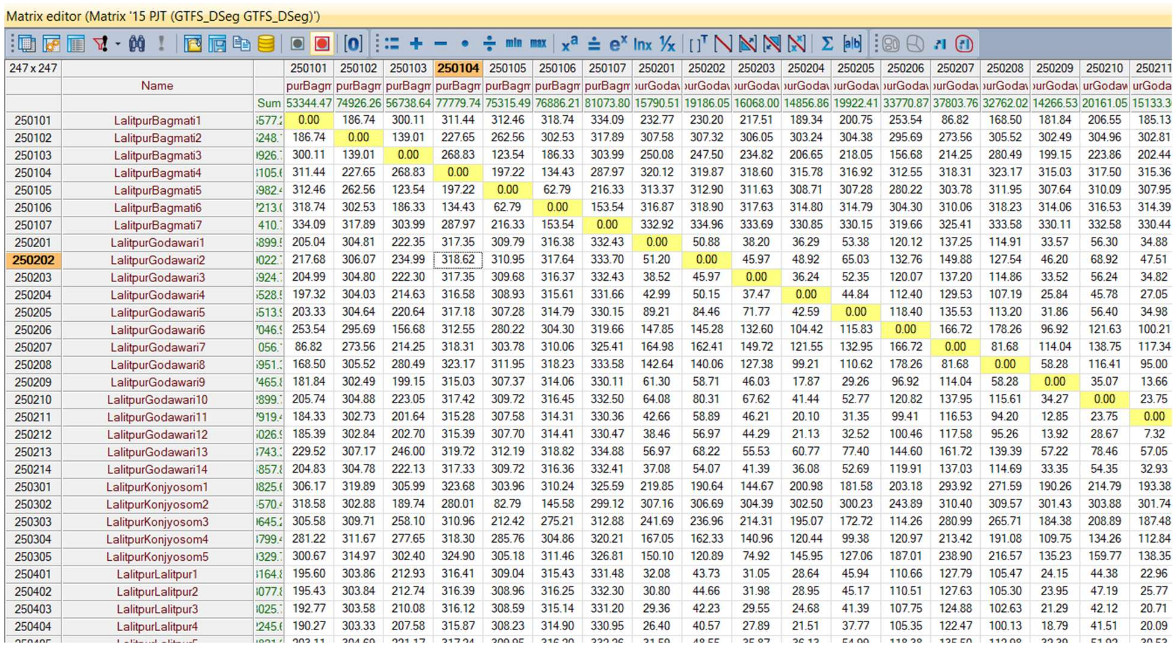

Modeling of zones, stops and lines in PTV Visum

| No | 17808 | 17809 | 17810 | 17811 | 17812 | 17813 | 17814 | 17815 | 17816 | 17817 | 17818 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | ax45kj_mCSnc | ax45kj_mCSnc | ax45kj_mCSnc | ax45kj_mCSnc | ax45kj_mCSnc | ax45kj_mCSnc | ax45kj_mCSnc | ax45kj_mCSnc | ax45kj_mCSnc | ax45kj_mCSnc | ax45kj_mCSnc |
| LineName | reli-Kamalbina | reli-Kamalbina | reli-Kamalbina | reli-Kamalbina | reli-Kamalbina | reli-Kamalbina | reli-Kamalbina | reli-Kamalbina | reli-Kamalbina | reli-Kamalbina | reli-Kamalbina |
| DirectionCode | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Concatenate:VehJourneySections\ValidDay | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| FromTProfItemIdentifier | 1MNxBukR2nt | 1MNxBukR2nt | 1MNxBukR2nt | 1MNxBukR2nt | 1MNxBukR2nt | 1MNxBukR2nt | 1MNxBukR2nt | 1MNxBukR2nt | 1MNxBukR2nt | 1MNxBukR2nt | 1MNxBukR2nt |
| Dep | 07:00:00 | 07:30:00 | 08:00:00 | 08:30:00 | 09:00:00 | 09:30:00 | 10:00:00 | 10:30:00 | 11:00:00 | 11:30:00 | 12:00:00 |
| Arr | 07:33:55 | 08:03:55 | 08:33:55 | 09:03:55 | 09:33:55 | 10:03:55 | 10:33:55 | 11:03:55 | 11:33:55 | 12:03:55 | 12:33:55 |
| ToTProfItemIdentifier | ҷmD3Nza0dZr | ҷmD3Nza0dZr | ҷmD3Nza0dZr | ҷmD3Nza0dZr | ҷmD3Nza0dZr | ҷmD3Nza0dZr | ҷmD3Nza0dZr | ҷmD3Nza0dZr | ҷmD3Nza0dZr | ҷmD3Nza0dZr | ҷmD3Nza0dZr |
| OperatorIdentifier | | | | | | | | | | | |
| CountVehJourneySections | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| IsCoupled | | | | | | | | | | | |

| 27 vehicle journey sections | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| VehCombIdentifier | | | | | | | | | | | |
| ValidDaysIdentifier | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 |
| FromTProfItemIdentifier | 1MNxBukR2nt | 1MNxBukR2nt | 1MNxBukR2nt | 1MNxBukR2nt | 1MNxBukR2nt | 1MNxBukR2nt | 1MNxBukR2nt | 1MNxBukR2nt | 1MNxBukR2nt | 1MNxBukR2nt | 1MNxBukR2nt |
| Dep | 07:00:00 | 07:30:00 | 08:00:00 | 08:30:00 | 09:00:00 | 09:30:00 | 10:00:00 | 10:30:00 | 11:00:00 | 11:30:00 | 12:00:00 |
| Arr | 07:33:55 | 08:03:55 | 08:33:55 | 09:03:55 | 09:33:55 | 10:03:55 | 10:33:55 | 11:03:55 | 11:33:55 | 12:03:55 | 12:33:55 |
| ToTProfItemIdentifier | ҷmD3Nza0dZr | ҷmD3Nza0dZr | ҷmD3Nza0dZr | ҷmD3Nza0dZr | ҷmD3Nza0dZr | ҷmD3Nza0dZr | ҷmD3Nza0dZr | ҷmD3Nza0dZr | ҷmD3Nza0dZr | ҷmD3Nza0dZr | ҷmD3Nza0dZr |
| PrePrepTime | 0min | 0min | 0min | 0min | 0min | 0min | 0min | 0min | 0min | 0min | 0min |
| PostPrepTime | 0min | 0min | 0min | 0min | 0min | 0min | 0min | 0min | 0min | 0min | 0min |

| ObjNo | Obj Code | ObjName | Arr / Dep | Arr / Dep | Arr / Dep | Arr / Dep | Arr / Dep | Arr / Dep | Arr / Dep | Arr / Dep | Arr / Dep | Arr / Dep | Arr / Dep |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4323 | Z1MNx | Chareli | 07:00:00 | 07:30:00 | 08:00:00 | 08:30:00 | 09:00:00 | 09:30:00 | 10:00:00 | 10:30:00 | 11:00:00 | 11:30:00 | 12:00:00 |
| 4324 | a3MfYi | Stop | 07:03:04 | 07:33:04 | 08:03:04 | 08:33:04 | 09:03:04 | 09:33:04 | 10:03:04 | 10:33:04 | 11:03:04 | 11:33:04 | 12:03:04 |
| 4325 | Rfk-8iF | Jhapro | 07:05:33 | 07:35:33 | 08:05:33 | 08:35:33 | 09:05:33 | 09:35:33 | 10:05:33 | 10:35:33 | 11:05:33 | 11:35:33 | 12:05:33 |
| 4326 | QDkkK | Chareli | 07:09:59 | 07:39:59 | 08:09:59 | 08:39:59 | 09:09:59 | 09:39:59 | 10:09:59 | 10:39:59 | 11:09:59 | 11:39:59 | 12:09:59 |
| 4327 | BzsWv | Stop | 07:11:19 | 07:41:19 | 08:11:19 | 08:41:19 | 09:11:19 | 09:41:19 | 10:11:19 | 10:41:19 | 11:11:19 | 11:41:19 | 12:11:19 |
| 4328 | Vb26m | Stop | 07:15:49 | 07:45:49 | 08:15:49 | 08:45:49 | 09:15:49 | 09:45:49 | 10:15:49 | 10:45:49 | 11:15:49 | 11:45:49 | 12:15:49 |
| 4329 | wx5Ww | Sudal wada karyalaya | 07:19:09 | 07:49:09 | 08:19:09 | 08:49:09 | 09:19:09 | 09:49:09 | 10:19:09 | 10:49:09 | 11:19:09 | 11:49:09 | 12:19:09 |
| 4330 | _L8QW | Jitpur | 07:20:09 | 07:50:09 | 08:20:09 | 08:50:09 | 09:20:09 | 09:50:09 | 10:20:09 | 10:50:09 | 11:20:09 | 11:50:09 | 12:20:09 |
| 4331 | mJ_1U | Jitpur | 07:21:09 | 07:51:09 | 08:21:09 | 08:51:09 | 09:21:09 | 09:51:09 | 10:21:09 | 10:51:09 | 11:21:09 | 11:51:09 | 12:21:09 |
| 4332 | Nxl_ZT | Stop | 07:25:41 | 07:55:41 | 08:25:41 | 08:55:41 | 09:25:41 | 09:55:41 | 10:25:41 | 10:55:41 | 11:25:41 | 11:55:41 | 12:25:41 |

Creating of time table schedules based on terminal frequency



Matrix editor (Matrix '15 PJT (GTFS_DSeg GTFS_DSeg)')

| 247 x 247 | Name | | 250101 | 250102 | 250103 | 250104 | 250105 | 250106 | 250107 |
|---|---|---|---|---|---|---|---|---|---|
| | | | purBagm | purBagm | purBagm | purBagm | purBagm | purBagm | purBagm |
| | | Sum | 53344.47 | 74926.26 | 56738.64 | 77779.74 | 75315.49 | 76886.21 | 81073.80 |
| 250101 | LalitpurBagmati1 | 577. | 0.00 | 186.74 | 300.11 | 311.44 | 312.46 | 318.74 | 334.09 |
| 250102 | LalitpurBagmati2 | 248. | 186.74 | 0.00 | 139.01 | 227.65 | 262.56 | 302.53 | 317.89 |
| 250103 | LalitpurBagmati3 | 926. | 300.11 | 139.01 | 0.00 | 268.83 | 123.54 | 186.33 | 303.99 |
| 250104 | LalitpurBagmati4 | 105. | 311.44 | 227.65 | 268.83 | 0.00 | 197.22 | 134.43 | 287.97 |
| 250105 | LalitpurBagmati5 | 982. | 312.46 | 262.56 | 123.54 | 197.22 | 0.00 | 62.79 | 216.33 |
| 250106 | LalitpurBagmati6 | 213. | 318.74 | 302.53 | 186.33 | 134.43 | 62.79 | 0.00 | 153.54 |
| 250107 | LalitpurBagmati7 | 410. | 334.09 | 317.89 | 303.99 | 287.97 | 216.33 | 153.54 | 0.00 |
| 250201 | LalitpurGodawari1 | 899. | 205.04 | 304.81 | 222.35 | 317.35 | 309.79 | 316.38 | 332.43 |
| 250202 | LalitpurGodawari2 | 022. | 217.68 | 306.07 | 234.99 | 318.62 | 310.95 | 317.64 | 333.70 |
| 250203 | LalitpurGodawari3 | 924. | 204.99 | 304.80 | 222.30 | 317.35 | 309.68 | 316.37 | 332.43 |
| 250204 | LalitpurGodawari4 | 528. | 197.32 | 304.03 | 214.63 | 316.58 | 308.93 | 315.61 | 331.66 |
| 250205 | LalitpurGodawari5 | 513. | 203.33 | 304.64 | 220.64 | 317.18 | 307.28 | 314.79 | 330.15 |
| 250206 | LalitpurGodawari6 | 046. | 253.54 | 295.69 | 156.68 | 312.55 | 280.22 | 304.30 | 319.66 |
| 250207 | LalitpurGodawari7 | 056. | 86.82 | 273.56 | 214.25 | 318.31 | 303.78 | 310.06 | 325.41 |
| 250208 | LalitpurGodawari8 | 951. | 168.50 | 305.52 | 280.49 | 323.17 | 311.95 | 318.23 | 333.58 |
| 250209 | LalitpurGodawari9 | 465. | 181.84 | 302.49 | 199.15 | 315.03 | 307.37 | 314.06 | 330.11 |
| 250210 | LalitpurGodawari10 | 899. | 205.74 | 304.88 | 223.05 | 317.42 | 309.72 | 316.45 | 332.50 |
| 250211 | LalitpurGodawari11 | 919. | 184.33 | 302.73 | 201.64 | 315.28 | 307.58 | 314.31 | 330.36 |
| 250212 | LalitpurGodawari12 | 026. | 185.39 | 302.84 | 202.70 | 315.39 | 307.70 | 314.41 | 330.47 |
| 250213 | LalitpurGodawari13 | 743. | 229.52 | 307.17 | 246.00 | 319.72 | 312.19 | 318.82 | 334.88 |
| 250214 | LalitpurGodawari14 | 857. | 204.83 | 304.78 | 222.13 | 317.33 | 309.72 | 316.36 | 332.41 |
| 250301 | LalitpurKonjyosom1 | 825. | 306.17 | 319.89 | 305.99 | 323.68 | 303.96 | 310.24 | 325.59 |
| 250302 | LalitpurKonjyosom2 | 570. | 318.58 | 302.88 | 189.74 | 280.01 | 82.79 | 145.58 | 299.12 |
| 250303 | LalitpurKonjyosom3 | 645. | 305.58 | 309.71 | 258.10 | 310.96 | 212.42 | 275.21 | 312.88 |
| 250304 | LalitpurKonjyosom4 | 799. | 281.22 | 311.67 | 277.65 | 318.30 | 285.76 | 304.86 | 320.21 |
| 250305 | LalitpurKonjyosom5 | 329. | 300.67 | 314.97 | 302.40 | 324.90 | 305.18 | 311.46 | 326.81 |
| 250401 | LalitpurLalitpur1 | 164. | 195.60 | 303.86 | 212.93 | 316.41 | 309.04 | 315.43 | 331.48 |
| 250402 | LalitpurLalitpur2 | 077. | 195.43 | 303.84 | 212.74 | 316.39 | 308.96 | 316.25 | 332.30 |
| 250403 | LalitpurLalitpur3 | 025. | 192.77 | 303.58 | 210.08 | 316.12 | 308.59 | 315.14 | 331.20 |
| 250404 | LalitpurLalitpur4 | 245. | 190.27 | 303.33 | 207.58 | 315.87 | 308.23 | 314.90 | 330.95 |

| 247 x 247 | 250201 | 250202 | 250203 | 250204 | 250205 | 250206 | 250207 | 250208 | 250209 | 250210 | 250211 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | urGoda | urGoda | urGoda | urGoda | urGoda | urGoda | urGoda | urGoda | urGoda | urGodaw | urGoda |
| | 15790.51 | 19186.05 | 16068.00 | 14856.86 | 19922.41 | 33770.87 | 37803.76 | 32762.02 | 14266.53 | 20161.05 | 15133.3 |
| 250101 | 232.77 | 230.20 | 217.51 | 189.34 | 200.75 | 253.54 | 86.82 | 168.50 | 181.84 | 206.55 | 185.13 |
| 250102 | 307.58 | 307.32 | 306.05 | 303.24 | 304.38 | 295.69 | 273.56 | 305.52 | 302.49 | 304.96 | 302.81 |
| 250103 | 250.08 | 247.50 | 234.82 | 206.65 | 218.05 | 156.68 | 214.25 | 280.49 | 199.15 | 223.86 | 202.44 |
| 250104 | 320.12 | 319.87 | 318.60 | 315.78 | 316.92 | 312.55 | 318.31 | 323.17 | 315.03 | 317.50 | 315.36 |
| 250105 | 313.37 | 312.90 | 311.63 | 308.71 | 307.28 | 280.22 | 303.78 | 311.95 | 307.64 | 310.09 | 307.95 |
| 250106 | 316.87 | 318.90 | 317.63 | 314.80 | 314.79 | 304.30 | 310.06 | 318.23 | 314.06 | 316.53 | 314.39 |
| 250107 | 332.92 | 334.96 | 333.69 | 330.85 | 330.15 | 319.66 | 325.41 | 333.58 | 330.11 | 332.58 | 330.44 |
| 250201 | 0.00 | 50.88 | 38.20 | 36.29 | 53.38 | 120.12 | 137.25 | 114.91 | 33.57 | 56.30 | 34.88 |
| 250202 | 51.20 | 0.00 | 45.97 | 48.92 | 65.03 | 132.76 | 149.88 | 127.54 | 46.20 | 68.92 | 47.51 |
| 250203 | 38.52 | 45.97 | 0.00 | 36.24 | 52.35 | 120.07 | 137.20 | 114.86 | 33.52 | 56.24 | 34.82 |
| 250204 | 42.99 | 50.15 | 37.47 | 0.00 | 44.84 | 112.40 | 129.53 | 107.19 | 25.84 | 45.78 | 27.05 |
| 250205 | 89.21 | 84.46 | 71.77 | 42.59 | 0.00 | 118.40 | 135.53 | 113.20 | 31.86 | 56.40 | 34.98 |
| 250206 | 147.85 | 145.28 | 132.60 | 104.42 | 115.83 | 0.00 | 166.72 | 178.26 | 96.92 | 121.63 | 100.21 |
| 250207 | 164.98 | 162.41 | 149.72 | 121.55 | 132.95 | 166.72 | 0.00 | 81.68 | 114.04 | 138.75 | 117.34 |
| 250208 | 142.64 | 140.06 | 127.38 | 99.21 | 110.62 | 178.26 | 81.68 | 0.00 | 58.28 | 116.41 | 95.00 |
| 250209 | 61.30 | 58.71 | 46.03 | 17.87 | 29.26 | 96.92 | 114.04 | 58.28 | 0.00 | 35.07 | 13.66 |
| 250210 | 64.08 | 80.31 | 67.62 | 41.44 | 52.77 | 120.82 | 137.95 | 115.61 | 34.27 | 0.00 | 23.75 |
| 250211 | 42.66 | 58.89 | 46.21 | 20.10 | 31.35 | 99.41 | 116.53 | 94.20 | 12.85 | 23.75 | 0.00 |
| 250212 | 38.46 | 56.97 | 44.29 | 21.13 | 32.52 | 100.46 | 117.58 | 95.26 | 13.92 | 28.67 | 7.32 |
| 250213 | 56.97 | 68.22 | 55.53 | 60.77 | 77.40 | 144.60 | 161.72 | 139.39 | 57.22 | 78.46 | 57.05 |
| 250214 | 37.08 | 54.07 | 41.39 | 36.08 | 52.69 | 119.91 | 137.03 | 114.69 | 33.35 | 54.35 | 32.93 |
| 250301 | 219.85 | 190.64 | 144.67 | 200.98 | 181.58 | 203.18 | 293.92 | 271.59 | 190.26 | 214.79 | 193.38 |
| 250302 | 307.16 | 306.69 | 304.39 | 302.50 | 300.23 | 243.89 | 310.40 | 309.57 | 301.43 | 303.88 | 301.74 |
| 250303 | 241.69 | 236.96 | 214.31 | 195.07 | 172.72 | 114.26 | 280.99 | 265.71 | 184.38 | 208.89 | 187.48 |
| 250304 | 167.05 | 162.33 | 140.96 | 120.44 | 99.38 | 120.97 | 213.42 | 191.08 | 109.75 | 134.26 | 112.84 |
| 250305 | 150.10 | 120.89 | 74.92 | 145.95 | 127.06 | 187.01 | 238.90 | 216.57 | 135.23 | 159.77 | 138.35 |
| 250401 | 32.08 | 43.73 | 31.05 | 28.64 | 45.94 | 110.66 | 127.79 | 105.47 | 24.15 | 44.38 | 22.96 |
| 250402 | 30.80 | 44.66 | 31.98 | 28.95 | 45.17 | 110.51 | 127.63 | 105.30 | 23.95 | 47.19 | 25.77 |
| 250403 | 29.36 | 42.23 | 29.55 | 24.68 | 41.39 | 107.75 | 124.88 | 102.63 | 21.29 | 42.12 | 20.71 |
| 250404 | 26.40 | 40.57 | 27.89 | 21.51 | 37.77 | 105.35 | 122.47 | 100.13 | 18.79 | 41.51 | 20.09 |

Calculation of travel time between zones

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# Evaluating Public Transport Accessibility for Work Trips: A Case Study of Kathmandu Valley

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**Abstract**
Public transport accessibility plays a vital role in sustainable urban mobility, influencing employment opportunities and economic participation. In rapidly urbanizing regions like Kathmandu Valley, inadequate and unstructured public transport systems lead to congestion, increased dependence on private vehicles, and limited accessibility to workplaces. This study assesses public transport accessibility to workplaces in Kathmandu Valley by employing the travel time ranges as per Public Transport and Walk Accessibility Index (PTWAI). A travel time matrix was generated using PTV Visum, incorporating public transport networks, walkability factors, and operational headways. Accessibility scores were weighted using employment data to reflect work trip demand. Results indicate that 66 wards (10.37% of the population) exhibit low accessibility, while 112 wards (47.65%) have moderate accessibility, and 69 wards (41.99%) enjoy high accessibility. Municipality-wise analysis reveals that rural municipalities, particularly Konjyosom, Bagmati, and Mahakal, suffer from the lowest accessibility, whereas Kathmandu Metropolitan City demonstrates the highest accessibility.

**Keywords**
public transport, accessibility, travel time

## 1. Introduction

Accessibility refers to people's ability to reach desired services and activities, which is the ultimate goal of most transport activity [1]. Access to public transport is crucial for sustainable urban mobility. It influences employment opportunities and economic participation and is a key component of integrated transport planning [2]. In South Asian cities such as Kathmandu, high population density, informal settlements, and limited road infrastructure pose significant challenges to accessibility. There is a need for inclusive and affordable transport to manage congestion and improve urban livability.Kathmandu Valley's rapid urban expansion has strained transport infrastructure, contributing to congestion, pollution, and rising accident risks. In Bagmati province, motorbikes account for 79.1% of vehicles, while public transport comprises only 2.67% [3]. The 14% annual vehicle growth rate further pressures the transport network, underscoring the need for improved public transport accessibility.

Unplanned urbanization and rising transportation activities have intensified congestion and environmental issues, highlighting the need for an efficient public transport system.The lack of reliable public transport has led many residents toward private vehicles, particularly motorcycles. Sustainable mobility requires a shift from road expansion to demand management, with public transport playing a key role. Although accessibility studies exist, research on informal and unscheduled transport systems, such as Kathmandu, remains limited [4]. Additionally, there is insufficient research on workplace accessibility disparities across Kathmandu Valley's wards.

This study quantifies public transport accessibility to workplaces in Kathmandu Valley, identifying underserved areas and providing insights for transport planning. Enhancing public transport accessibility can reduce reliance on private vehicles, alleviate congestion, and contribute to a more sustainable urban mobility system.

## 2. Literature Review

### 2.1 Methods of Measuring Accessibility:

Accessibility has wide range of dimensions which includes, spatial separation (i.e. travel time, travel cost, information, reliability), origins (locations, person), destination (job, people, services, facilities), geographical scale (like regional scale), travel modes (public, private), route choice, time of day, environmental impact, and topographic features. Existing studies have various understandings and definitions of accessibility, which result in different ways of calculation and modeling. Hansen created the concept of accessibility on transportation as the size of interaction opportunities of nodes in traffic networks, and the Hansen Gravity Model was established in the process of distributing the forecasted metropolitan population to small areas within the metropolitan region [5]. Kwan indicate that the geographical access can be conceived as an attribute of either location (place accessibility) or individuals (personal accessibility), and can be evaluated at a global and local scale, embedding time or otherwise [6].

Other measures like minimum travel time and the shortest travel distance [7], the difficulty for the OD points to overcome the space separation contact[8] and the number of opportunities that can be obtained in the range of unit time or unit distance[9] have been mostly used as well. However in recent times, the number and diversity of destinations that travelers can reach [10], and the potentials of interaction or contact between OD points[11] are used. Existing accessibility measures can be categorized into three main groups, including access to public transport stops, duration of a journey by public transport and access to a destination via public transport modes[12]. In recent researches, the accessibility score is give based on different approaches like Public Transport Accessibility Level (PTAL) and Supply Index (SI) have been used. The PTAL uses the Waiting time, service waiting time and total access time and groups the accessibility index into 0(worst) to 6b(best)[13]. The Supply index incorporates population density to accessibility calculations.The researchers introduce a modified gravity-based measure that accounts for service frequency,travel time to key destinations,waiting and transfer times,socioeconomic factors [14]. The Structural Accessibility Level (SAL) includes the land-use and transport components, but not the temporal and individual components[15]. It includes two accessibility measures, the diversity of activity index (DivAct) and a comparative accessibility measure (accessibility cluster) for categorization.In a comparative study conducted in Helsinki, researchers evaluated two location-based methods for assessing public transport accessibility: the Structural Accessibility Layer (SAL) and the PTWAI [16].

### 2.2 PTWAI Approach:

The PTWAI is a measure used to calculate accessibility for public transport and walking [12]. All land parcels within the service areas were assigned an accessibility score from 0 to 4, based on the travel times. A score of 0 indicates a travel time exceeding 60 min travel by transit and on foot along the road network to get to the destination. A score of 4 represents high accessibility and means that the destination is accessible within 10 min transit and walking travel.

| Accessibility score | Threshold times (minutes) |
|---|---|
| 0 | >60 |
| 1 | 40–60 |
| 2 | 20–40 |
| 3 | 10–20 |
| 4 | 0–10 |

**Table 1:** Threshold Times for Accessibility Score[12]

PTWAI has been used in urban planning to identify low-accessibility zones and guide strategic transport investments. Given the informal and unscheduled nature of public transport in Kathmandu Valley, adopting a PTWAI-based accessibility approach can provide crucial insights for addressing mobility gaps and ensuring equitable access for work trips.

### 2.3 Visum in Public Transportation Analysis:

PTV Visum is a widely used transport planning software that enables comprehensive analysis of public transportation networks, including accessibility assessment, demand modeling, and service optimization. Several studies have used Visum's capabilities to assess and improve public transport efficiency. Visum was used to optimize transit routes, reducing travel times and operational costs [17]. Multimodal networks were integrated in Visum for improved analysis [18]. Visum was employed to evaluate and enhance the public transportation system of Denizli, Turkey, using a Potential Accessibility (PA) measure as a key metric to assess network efficiency and identify areas requiring service improvements [19].

Visum provides three assignment methods for public transportation;transport system-based procedure, headway-based procedure, timetable-based procedure. The headway-based procedure is ideal for urban networks with short headway and for long-term conceptual planning, as long as the timetable for the period being analyzed is still unknown. The headway based procedure determines the transfer wait time at transfer stops from the mean headway of the succeeding lines. Doing without the timetable on the level of individual trips ensures short computing times even for large networks. In the context of Kathmandu Valley, where public transport is often fragmented and operates without fixed timetables, the headway-based assignment method in Visum becomes especially valuable. This approach does not require predefined schedules or detailed timetables, making it suitable for areas with informal, unscheduled transport systems, which are common in Kathmandu.

## 3. Methodology

This study aims to calculate a weighed accessibility value for measuring the level of work accessibility to public transport in Kathmandu valley's 247 wards, the smallest administrative unit served as basic units of analysis where population data are aggregated to its centroid. Each ward's geometric center serves as the origin and destination for trips.The public bus network of Kathmandu valley is built and analyzed in QGIS. The city base map is taken with the plugin QuickOSM from QGIS for the study area. The boundary information is obtained from the Department of Survey, Government of Nepal.

There is currently no structured database for the route permit system maintained by government agencies in Nepal. Furthermore, a significant number of routes are operated by various operators in an uncoordinated and fragmented manner. The Public Transport Restructuring Project supported by the ADB in 2014 [20], as part of the Kathmandu Sustainable Urban Transport Project (KSUTP), mentions operation of around 200 routes, many of which overlapped, and recommended a restructuring of the routes. A more recent study by FCCPTA in 2024 listed 132 public transport routes in the Valley, based on inquiries with operators and transportation associations [21]. Furthermore, Transport Office in Ekantakuna is working to digitalize the route information and reports the existence of approximately 72 bus and minibus routes along with 15 microbus and tempo routes.

### 3.1 Data Collection

Under ADB's Sustainable E-Mobility Project(SUEP),a total of 133 onboard surveys were conducted from 22 September 2024 to 1 October 2024, during peak hours excluding Fridays after 2 PM and Saturdays or public holidays to ensure data uniformity. The survey was conducted in both directions in which stop locations and the timestamps for arrival and departure at each stop were recorded. The headways were manually collected at the terminals by interviewing the drivers, conductors and by waiting for the next departure.

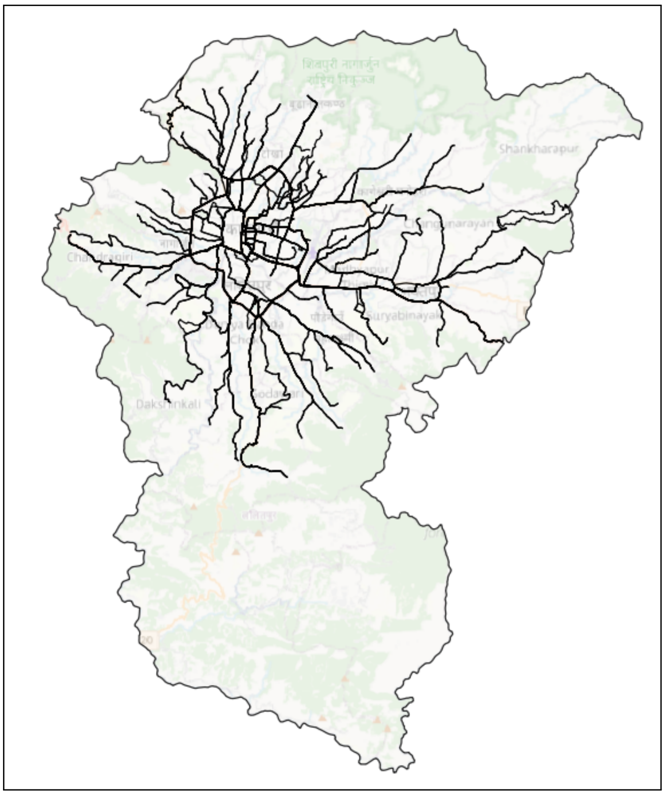


**Figure 1:** Public Transport Routes operating within the valley

## 3.2 Travel Time Calculation

The shapefiles from the onboard survey and the frequency data were processed by python code and converted into GTFS format. The GTFS feed, boundary informations, city base map were supplied to PTV Visum. A 247 × 247 travel time matrix is developed to capture travel times between each OD pair based on minimum impedance which is the perceived journey time.

The Perceived Journey Time(PJT) for each origin-destination (OD) pair is computed in VISUM as:

$$\begin{aligned} PJT = &\text{ In-vehicle time} + \text{Access time} + \text{Egress time} \\ &+ \text{Transfer walk time} + \text{Origin wait time} \\ &+ \text{Transfer wait time} \end{aligned} \tag{1}$$

### 3.2.1 Wait Time

The waiting time is the average time between arriving at a stop and the arrival time of public transport. For each selected route, the waiting time was considered as the interval between services. If the frequency is 6 vehicles/hr, the headway is 10 minutes/vehicle and the wait time will be 5 minutes.

$$WaitTime_{ij} = 0.5 \times \left( \frac{60}{Frequency_{ij}} \right) \tag{2}$$

### 3.2.2 Walk Time

The access and egress times are determined using the shortest path computed via Dijkstra's algorithm. The OSM road network is imported in python via geopandas and a Network X graph is created from the road network. Walk distances were converted to a measure of time assuming an average walk speed of 1.2m/s [22].

## 3.3 Work Accessibility Score

Accessibility scores are assigned based on travel time ranges as defined in Table 1. The number of people working in each ward and the total workers of three districts of Kathmandu valley is taken from the National Economic Census 2018, compiled by the National Planning Commission (CBS) [23].The accessibility score for each OD pair is weighted based on employment data of each ward.

$$\text{Work Accessibility Score}_{ward\,i} = \sum_j \left( \text{Accessibility score}_{(i,j)} \times \frac{\text{People working in ward }_j}{\text{Total workers}} \right) \tag{3}$$

# 4. Result and Discussion

By use of python, the travel time is converted into accessibility scores and subsequently into the weighted accessibility scores.The weighted accessibility score ranged from score of 0.00 to 2.56.

## 4.1 Work Accessibility Score Analysis by Ranges:

Table 2 categorizes wards in Kathmandu Valley based on their Work Accessibility Scores, which indicate the accessibility of public transportation based on walkability. The results show 66 wards (10.37% population) have a low work accessibility score (<1), indicating poor walk accessibility to public transport.

112 wards (47.65% population) fall within the moderate range (1–2), suggesting relatively balanced accessibility. 69 wards (41.99% population) exhibit a high accessibility score (>2), meaning these areas have better access to work using public transportation. Just more than 50% of the valley's population and 71.65% of the valley's wards are within lower to moderate accessibility. The presence of 66 wards with low accessibility indicates gaps in the public transport network that may require targeted interventions.

| Ranges | Accessibility | Wards | Population |
|---|---|---|---|
| <1 | Low | 66 | 10.37% |
| 1-2 | Moderate | 112 | 47.65% |
| >2 | High | 69 | 41.99% |
| **Total** | | **247** | |

**Table 2:** Work Accessibility Score Analysis by Ranges

Figure 2 represents the work accessibility by public transportation mapping of wards of Kathmandu Valley. The darker wards represents higher work accessibility scores.

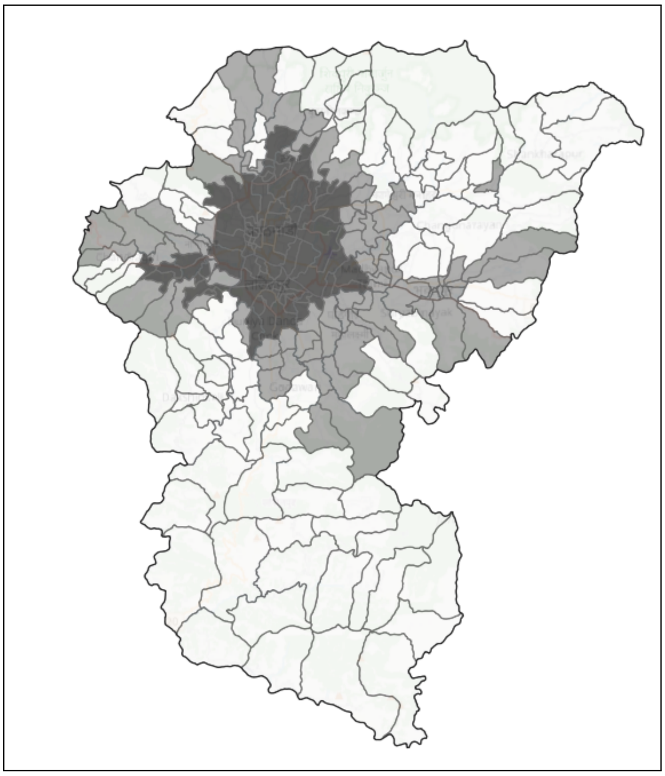

**Figure 2:** Work Accessibility Mapping of Wards

### 4.2 Municipality-wise Work Accessibility Comparison

| Municipality | Average Work Accessibility |
|---|---|
| Bagmati | 0.001 |
| Godawari | 0.950 |
| Konjyosom | 0.002 |
| Lalitpur | 1.975 |
| Mahalaxmi | 1.623 |
| Mahankal | 0.004 |
| Bhaktapur | 1.833 |
| Changunarayan | 0.949 |
| Madhyapur Thimi | 1.895 |
| Suryabinayak | 1.487 |
| Budhanilakantha | 1.512 |
| Chandragiri | 1.589 |
| Dakshinkali | 0.430 |
| Gokarneshwor | 1.178 |
| Kageshwori Manahora | 1.272 |
| Kathmandu | 2.189 |
| Kirtipur | 1.876 |
| Nagarjun | 1.427 |
| Shankharapur | 0.478 |
| Tarakeshwor | 1.473 |
| Tokha | 1.954 |

**Table 3:** Municipality-wise Average Work Accessibility

Table 3 presents the average work accessibility across different municipalities in Kathmandu Valley.Kathmandu Metropolitan has the highest work accessibilities, suggesting that public transport is more accessible within the core urban area. Other municipalities such as Lalitpur, Bhaktapur , and Tokha also show high accessibility, which can be attributed to well-established road networks and a dense public transport system with higher working population available near their peripheries.

Peripheral municipalities such as Konjyosom , Mahankal , Bagmati, and Shankharapur have the lowest work accessibility scores, reflecting poor public transport accessibility. These areas likely suffer from inadequate public transport infrastructure, low population density, or difficult terrain, making it challenging for residents to access transit services.

## 5. Conclusion

This study provides a comprehensive analysis of work accessibility in Kathmandu Valley using a travel time-based approach, incorporating travel time components and employment data. The findings reveal significant spatial disparities in public transport accessibility, with urban core areas demonstrating higher accessibility levels, while peripheral and rural municipalities suffer from inadequate transit connectivity.The presence of low-accessibility zones highlights gaps in service coverage and the necessity for better-planned transport policies. Strengthening public transport networks through improved route coordination, increased service frequency, and enhanced first- and last-mile connectivity can foster a more equitable and efficient urban mobility system.

Future research could further explore dynamic accessibility changes over time and incorporate additional factors such as fare affordability, multimodal transport integration to enhance urban accessibility assessments and analyze the effects of policy changes, such as the introduction of electric buses or route restructuring, on accessibility outcomes. By addressing accessibility disparities and improving public transport efficiency, Kathmandu Valley can move towards a more sustainable and equitable urban transport system.

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